Understanding the Difference between Farmers' and Experts' Livelihood Perspectives: The Structured Mental Model Approach (Case study: Pesticide use in Vereda la Hoya, Colombia)

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Zusammenfassung

Die vorliegende Doktorarbeit hat zum Ziel, das Denken im Zusammenhang mit der Anwendung von Pestiziden zu ergründen und besser verstehen zu lernen. Als Fallbeispiel dient dazu die Region Vereda la Hoya (Tunja; Kolumbien) und die dort ansässigen kartoffelnproduzierenden Bauern. Zur Erarbeitung des Ziels wurden mentale Modelle (MM) der Anwendung von Pestiziden mit Hilfe eines dazu speziell entwickelten Ansatzes, dem Strukturierter Mentale Modelle Ansatz (SMMA), erhoben. Konkret wurden die MM von Bauern und Experten bezüglich der gegenwärtigen Anwendung von Pestiziden (Gegenwarts Mentale Modelle (GMM)), sowie die MM bezüglich der zukünftigen Anwendung von Pestiziden (Zukunfts Mentale Modelle (ZMM)), erhoben und miteinander verglichen. Abschliessend wurden die GMM und ZMM der Bauern miteinander verglichen und daraus Abhängigkeiten der MM untereinander abgeleitet.

Trotz grosser Fortschritte im Pflanzenschutz benötigt die Kontrolle von Schädlingen immer noch ein hohes Mass an Pestiziden. Wie aus verschiedenen früheren Studien bekannt ist, kann die unsachgemässe Anwendung von Pestiziden zu hohen Umweltschäden führen, insbesondere zu Bodendegradation und -kontamination und auch zu Biodiversitätsverlusten in Bodensystemen. Darüber hinaus beeinflussen Pestizide auch Humansysteme und können eine Reaktionskette auslösen, welche bis zur Blockierung des Neuromuskularsystems führen können. Viele Chlorinate können Leber- und Nierenschäden auslösen und das Zentralnervensystem beeinflussen. Weitere Gesundheitseffekte, die durch die aktiven Komponenten der Pestizide ausgelöst werden, sind Kopfschmerzen, Schwindelgefühl, Augenirritationen und Hautrötungen.

Die unsachgemässe Anwendung von Pestiziden in Entwicklungsländern lässt sich in vier Problemfelder gliedern: (i) unzureichende Verwendung von Schutzkleidung beim Mixen und Auftragen der Pestizide; (ii) unsachgemässe Lagerung der Pestizide; (iii) höhere Anwendungsraten und (iv) Nutzung toxischerer Produkte als in Industrieländern. All diese Probleme lassen sich mit bekannten Kognitions- und Risikowahrnehmungs-Theorien untersuchen. Um die Entscheidungsprozesse in risikobehafteten Situationen zu analysieren, besteht in der Forschung der Risikowahrnehmung eine lange Tradition der Analyse von MM. Um Entscheidungen der betroffenen Bevölkerungsgruppen und Pestizidanwender in ländlichen Gebieten, vor allem in Entwicklungsländern, zu verstehen, wird in der entsprechenden Forschung seit Jahren eine Gliederung der Lebensumstände in so genannte Lebensumstandskapitalien (Human-, Physisches-, Natur-, Finanz- und Sozialkapital) durchgeführt.

Um die dargelegten Pestizidnutzungsprobleme vor dem Hintergrund der Risikowahrnehmung und der Lebensumstände der Bauern anzugehen, wurden in der vorliegenden Doktorarbeit die folgenden Fragen bearbeitet: 1) Wie nehmen die Bauern die Risiken im Zusammenhang mit Pestizidnutzung wahr und wie beeinflussen die Lebensumstände der Bauern ihre Risikowahrnehmung? 2) Was stellen sich die Bauern für ihre Zukunft allgemein und, im Hinblick auf Pestizidnutzung im Besonderen, vor und wie beeinflussen die Lebensumstände der Bauern ihre Zukunftsvorstellungen? 3) Wie können die MM bezüglich der Gegenwart und der Zukunft der Bauern verglichen und welche Schlussfolgerungen können im Bezug auf Risikowahrnehmung daraus gezogen werden? Die vorliegende Arbeit ist in vier Teile gegliedert, jeder Teil befasst sich mit einem anderen Aspekt des Denkens im Zusammenhang mit der Anwendung von Pestiziden.

Im ersten Teil der Arbeit wird der SMMA entwickelt und vorgestellt. Der SMMA ist ein methodologischer Ansatz der darauf abzielt, die MM von Experten und Bauern zu erheben und Unterschiede in den MM aufzuzeigen und zu verstehen. Im SMMA werden der Sustainable Livelihood Framework (SLF) und der Mental Models Approach (MMA) kombiniert. Dieser Ansatz besteht aus drei Stufen: (i) Definition und Gewichtung der verschiedenen individuellen Lebensumstandskapitalien (Human-, Physisches-, Natur- und Finanzkapital), (ii) Analyse der dynamischen Zusammenhänge zwischen den individuellen Lebensumstandskapitalien und (iii) Definition sowie Gewichtung des Sozialkapitals. Dank der vorgeschlagenen Methodologie gelangt man einerseits zu einem tieferen Verständnis der Risikobeurteilung der Bauern und deren Prioritäten, andererseits gewinnt man ein grundlegendes Verständnis für die Ursachen von Wahrnehmungsunterschieden zwischen Bauern und Experten.

Im zweiten Teil der Arbeit werden die Resultate der ersten Anwendung des SMMA im Untersuchungsbiet Vereda La Hoya analysiert. Das Untersuchungsgebiet Vereda la Hoya charakterisiert sich durch Subsistenzlandwirtschaft, einem hohen Gebrauch von Pestiziden und einem erhöhten Auftreten von Gesundheitsproblemen. Die Hypothese für das Untersuchungsgebiet ist, dass Subsistenzlandwirtschaft durch ökonomische, ökologische und sozio-kulturelle Faktoren eingeschränkt ist welche die MM der Bauern beeinflussen. Dreizehn Experten und zehn Bauern des Untersuchungsgebietes wurden interviewt und deren MM ihrer Lebensumstände, erhoben. Die Fragen in den Interviews wurden offen gestellt und die Interviews in die drei Teile des SMMA gegliedert. Dieser Struktur folgend wurde jeder Teil des Interviews qualitativ und statistisch analysiert.

Die Analyse zeigte, dass sich die MM der Bauern und der Experten im Hinblick auf die Definition und Interaktion der Lebensumstanskapitalien signifikant unterschieden. Des Weiteren wurden Gründe für die Divergenz der MM der Experten und Bauern identifizieren. Dabei zeigte sich anschaulich, das folgenden Faktoren die grösste Bedeutung zukommt: i) Kultur und Tradition, ii) Vertrauen in die Informationsquelle und iii) Rückkopplungsmechanismen des Wissens.

Ziel des dritten Teils der Arbeit war es, die Zukunftsvisionen der Bauern im Bezug auf Pestizidnutzung zu ermitteln, sodass der SMMA auf den Zukunftskontext angepasst wurde. (Zukunfts-SMMA). Anschliessend wurden zehn Bauern des Untersuchungsgebietes Vereda la Hoya mit dem Zukunfts-SMMA zu ihren Erwartungen für die Zukunft befragt. Die Zukunftsvisionen der Bauern wurden analysiert und es wurde festgestellt, dass die Bauern sowohl soziale, als auch umweltrelevante Gefahren in ihre Überlegungen mit einschliessen, und das ihre Zukunftsvisionen zumeist optimistisch sind. Zusätzlich wurden die Wahrnehmungen von Bauern und Experten, hinsichtlich externer Einschränkungen auf zukünftige Entwicklungsmöglichkeiten, verglichen, und für inkonsistent befunden. Abschliessend wurde erforscht, wie die Lebensumstände der Bauern und ihre Selbstwahrnehmung die Bildung ihrer Zukunftsvisionen beeinflusst. Es wurde festgestellt, dass eine erhöht differenzierte Wahrnehmung der gegenwärtigen Lebensumstände mit einer erhöhten Differenzierung zukünftiger Lebensumstände einhergeht. Abschliessend wurde festgehalten, dass die gefundenen Inkonsistenzen darauf zurück zu führen sind, dass die Befragten eine unterschiedliche Einstellung und Meinung darüber haben, wer die Verantwortung für die Zukunft übernehmen soll.

Im vierten und letzten Teil der Arbeit wurden der zweite und dritte Teil miteinander verglichen und Erkenntnisse über das Thema der Abhängigkeit von GMM und ZMM, in Bezug auf die Pestizidnutzung, gewonnen. Durch den Vergleich der kausalen Relationen in GMM und ZMM konnten die Ähnlichkeiten beider Modelle gemessen werden. Durch die Verwendung der Ähnlichkeit als ein Mass der Abhängigkeit, konnte die Abhängigkeit der ZMM von den GMM bestimmt werden. Die gefundene Abhängigkeit unterschied sich je nach befragtem Lebensumstandskapital und je nach befragtem Bauer. Die vier Individual-Kapitalien (Human-, Gesundheits-, Natur- und Finanzkapital) unterschieden sich substanziell im Ausmass der Abhängigkeit. Zusätzlich wurden drei Abhängigkeits-Typen von Bauern gefunden. Einige Bauern verwendeten zur Hauptsache die gleichen kausalen Relationen in den GMM und ZMM (Ursache und Wirkung), während andere Bauern sich mehr auf die Ursachen und wiederum andere mehr auf die Wirkungen ihrer GMM stützten, um das ZMM aufzubauen.

Es wurden folgende drei Erklärungen zu den unsachgemässen Anwendung von Pestiziden in Entwicklungsländern gefunden. Erstens die unzureichende Verwendung von Schutzkleidung beim Mixen und Auftragen der Pestizide konnte dadurch erklärt werden, dass die Bauern eine binäre Definition ihres Gesundheitskapitals aufweisen (entweder tot oder lebendig) und sich fatalistisch darüber zeigten wer ihren Gesundheitszustand bestimmt (nämlich Gott). Deswegen ergreifen Bauern andere Gesundheitsschutzmassnahmen als Experten es erwarten würden, wie z.B. Gesundheitsgebete. Zweitens die unsachgemässe Lagerung der Pestizide konnte dadurch erklärt werden, dass die Bauern mit einer Abnahme der Toxizität der Pestizide in der Zukunft rechen was zu einer erwarteten Abnahme der Bedeutung von Schutzmassnahmen führt und somit schon die gegenwärtige Wahrnehmung von Toxizitätsaspekten negative beeinträchtigt. Drittens die höhere Anwendungsraten von Pestiziden und die Nutzung toxischerer Produkte als in Industrieländern konnte durch die Erfahrung der Bauern mit dem Preis-Leistungs-Verhältnis der Pestizide erklärt werden. Neuere, weniger toxischere Pestizide, die auch in Industriestaaten Verwendung finden, werden von den Bauern als unbezahlbar wahrgenommen. So ziehen es die Bauern vor ältere, billigere Pestizide zu verwenden, obwohl sie diese als weniger zuverlässig einschätzen. Um dann die Nachteile älteren Pestizide zu überbrücken, verwenden die Bauern diese in höheren Raten als auf der Packung angegeben und bleiben der Überzeugung damit eine günstigere Pestizidbehandlung zu vollziehen als wenn sie neuere Produkte verwenden würden.
Unteranderem liessen sich folgende Empfehlungen für Entscheidungsträger aus den Erkenntnissen der Arbeit herleiten: 1) die spezielle Gesundheitsdefinition der Bauern sollte berücksichtigt werden um die gesundheitlichen Schutzmassnahmen der Bauern zu verbessern; 2) die Wahrnehmung und Erwartungshaltung der Bauern bezüglich Pestizidtoxizität sollte aufgenommen werden um die Lagerung der Pestizide zu verbessern; 3) die Bauern sollten unabhängige Informationen zu Preis-Leistung der Pestizide erhalten um den sachgemässen Umgang mit Pestiziden zu verbessern.

Der SMMA lässt sich auch auf einer Reihe andere Problemfelder der Landwirtschaft in Entwicklungsländern ausdehnen, so zum Beispiel auf Probleme der Wasserbewirtschaftung oder bei der Einführung neuer Bewirtschaftungspflanzen oder neuer Düngemittel. Durch die dortige Anwendung des SMMA liessen sich ähnliche Erkenntnisse und Empfehlungen wie im Fall der Pestizidproblematik finden, welche zur Lösungen auch jener Problemfelder führen könnten.

Executive summary

The main objective of this PhD thesis is to derive and understand the reasoning behind the use of pesticides. In this, the case of potato farmers in Vereda La Hoya (Tunja, Colombia) provided the applied context. To achieve this objective, the perception of the present situation of farmers and experts concerning risks of pesticide use were first derived and compared, and subsequently, the future visions of farmers and experts were analyzed. Finally the perception of the present situation and the future visions of farmers were compared and the differences found were discussed.

Despite improvements in plant protection, the control of plant pests still entails substantial use of pesticides. As known from several previous studies, inappropriate pesticide application can lead to high environmental damage, such as degradation and contamination of soils as well as deterioration of the biodiversity of the soil system. Furthermore pesticides impact humans directly and can induce a chain of direct responses leading to e.g. neuromuscular blockage. Many chlorinates can induce liver changes, kidney changes and depression of the central nervous system. Further health effects caused by the active components of pesticides are headache, nausea, fatigue, eye irritation and skin rash.
The inappropriate application of pesticides in developing countries is related to (i) lack of protection during the mixture and application procedure; (ii) inadequate storage facilities (iii) a higher rate of application compared to industrialized countries; (iv) use of more toxic products compared to industrialized countries. These problems can all be related to cognition theory and, specifically, to theories of risk perception. To investigate people's decisions in risk-related situations, risk perception research has a long tradition of analyzing mental models (MMs). To understand decision-making in rural areas, research in developing countries has a long tradition of structuring and analyzing livelihood assets of farmers as a context perspective. To tackle the pesticide problem presented, considering cognition and livelihood aspects, the following research questions were investigated: 1) How do farmers perceive the risks associated with pesticide application and how does farmers' livelihood context influence farmers' risk perception? 2) What do farmers envision for their future and their future pesticide use, and how does farmers' livelihood influence farmers' future visions concerning pesticide use? 3) How can farmers' present and future MMs be compared and what conclusion can be drawn concerning risk perception? The thesis is organized in four parts.

In the first part of the thesis the Structured Mental Model Approach (SMMA) is developed and presented. The SMMA is a methodological approach aimed at understanding differences in MMs between experts and farmers, regarding the risks farmers are confronted with. In the SMMA, the Sustainable Livelihood Framework (SLF) is combined with the Mental Models Approach (MMA), and a theoretically grounded and structured approach obtained. The approach consists of three steps: (i) definition and weighting of the different livelihood capitals; (ii) analysis of livelihood dynamics, and (iii) definition of the social capital. The proposed methodology on the one hand provides an understanding of farmers' risks and their priorities as seen by experts and farmers. On the other hand, it provides a preliminary understanding of the origins of differences between experts' and farmers' risk perception. The development of the SMMA led to the first publication.
In the second part of the thesis the results of the first application of the SMMA in the study area Vereda la Hoya are analyzed. The study region Vereda la Hoya is characterized by subsistence farming, high use of pesticides and a high incidence of health problems. The hypothesis is that subsistence farmers are constrained by economic, environmental and socio-cultural factors, which consequently influence farmers' MMs and makes farmers' MMs differ from the MMs of local experts. Thirteen experts and ten farmers were interviewed and their MMs of the extended pesticide system elicited. The interviews were open-ended with the questions structured in three parts: (i) definition and ranking of the individual capitals (human, health, natural and financial capital) with respect to their importance for the sustainability of farmers' livelihood; (ii) understanding the system and its dynamics; (iii) definition and construction of the social capital of a farmer (by analyzing farmers' agent networks with respect to composition and form of the network). Following this structure, each part of the interviews was analyzed qualitatively and statistically. The analysis showed that the MMs of farmers and experts differ significantly from each other with respect to definition of and interaction among the livelihood capitals. After analyzing the data obtained with the SMMA it was possible to identify reasons for the divergence of experts' and farmers' MMs. Of major importance are the following factors: i) culture and tradition; ii) trust in the source of information and iii) feedback on knowledge. The first application of the SMMA led to the second publication.
The goal of the third part of the thesis was to identify farmers' future visions concerning pesticide management. To achieve this goal the SMMA was adapted to the future context (Future-SMMA). Ten Vereda la Hoya farmers were interviewed concerning their future perspectives and expectations which lead to farmers' future visions. Subsequently, ten experts were interviewed about the feasibility and the consequences of farmers' future visions. Farmers' future visions were analyzed and it was found that farmers consider social and environmental threats and that their visions are optimistic. In addition farmers' and

experts' perception of external constraints to farmers' future were compared and it was discovered that the investigated future visions of farmers and experts are inconsistent with respect to the future development of the region. Finally after determining how farmers' livelihood assets and self-perception influence the construction of farmers' future visions, it was found that the more a person is able to differentiate his livelihood assets, the more differentiated the future visions of that person are. We conclude that the inconsistency of future visions found was caused by diverging attitudes towards future scenarios and different opinions about who should take responsibility for the knowledge management of the farmers. The SMMA adaptation and the findings of the application resulted in a third publication.
The fourth and last part compares the second and third parts of the PhD thesis and sheds light on the dependency of future on present MMs concerning pesticide use. By comparing the causal relations of present and future MMs, the similarities of future and present MMs were measured. Using similarity as a measure of dependency, the dependency of future on present MMs was derived. The dependency of future on present MMs that was found differed with respect to livelihood capitals and interviewed farmer. The four individual capitals differed substantially in degree of dependency (natural capital being most and health capital least dependent). Moreover three different farmer types with respect to dependence were found. Two groups of farmers mostly use the same causal relation (causes and effects) in the present and in the future MMs; whereby farmers of one of the groups focused more on the causes, and farmers of the other group more on the effects. A third group of farmers mostly used different causal relations in the present and in the future. The comparison of the SMMA and Future-SMMA data resulted in a fourth publication.

The following explanations to the current pesticide problems in developing countries were found. First the lack of protection during the mixture and application procedure are explained by farmers defining their health in a binary way (being either dead or alive) and being fatalistic about who influences their health (i.e. god). Therefore farmers take different health protection measures than experts were expecting, e.g. praying to stay healthy. Second the problem of inadequate storage facilities is explained by the fact that farmers expect pesticides to become less toxic and therefore the need for future protection was expected to become less important such also dampening the need for present protection. Third the problems of a higher rate of application and use of more toxic products compared to industrialized countries was found to be related to farmers' experiences with pesticides effectiveness compared to prices. New, less toxic and more efficient pesticides, like the ones used in industrialized countries, are perceived by farmers to be too expensive. Thus farmers prefer to stick to old, cheaper pesticides although they experienced them to be less reliable than new, expensive pesticides. To overcome deficiencies of old pesticides, farmers use these pesticides in higher rates than recommended.
Among others the following recommendations for policy makers were derived from the research findings: 1) farmers health capital definition has to be taken into account to improve farmers health protection; 2) farmers' perception and expectations concerning pesticide toxicity have to be addressed to improve pesticide storage; and 3) farmers have to be given independent price vs. efficiency information of their commonly used products to tackle farmers overdosage of older more toxic pesticides.

The application of the SMMA can be expanded to investigate other agricultural issues in developing countries, such as water management, crop selection or fertilizer application, leading to comparable findings and policy recommendations.

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1 Introduction

The aim of this synopsis is to frame the four scientific articles of which the thesis is composed of. The synopsis is structured in five parts: introduction, theoretical background, research design, summary of the publications and concluding remarks. The introduction section gives a general overview of the background of the thesis, provides an insight into the pesticide application problem and develops the research questions. The theoretical background provides an insight into the theory and the adaptations of the theory developed throughout this thesis. The research design section depicts the overview of the structure, i.e. how the four publications are interlinked and how they address the research questions. The summary of the publications section briefly presents the four publications. The concluding remark section wraps up the synopsis of the thesis, and provides a final discussion and conclusions of the integrated results, together with suggestions for further research.

Throughout the entire thesis for the expression “mental model” the abbreviation MM is used and likewise MMs for “mental models”. Furthermore “mental models of the present and the future” and “present and future mental models” are used as synonyms, meaning with both expressions mental models of present and future situations. Thus whenever the expression “present and future MMs” or “MMs of present and future“ are used we refer to mental models of present and future situations (likewise we refer with present MM, present MMs, future MM and future MMs to the mental model or the mental models of the respective time frame).

1.1 Starting point and relevance

1.1.1 Current situation of pesticide use

Despite considerable improvements in food production over the last 50 years, food security remains a problem in many parts of the world (Rosengrant and Cline 2003; 2005). According to the FAO’s latest estimates 852 million people were undernourished (between 2000-2002)(FAO 2005). One solution to feeding the growing world population are fertilizers and pesticides. Therefore since and due to the green revolution, the use of chemical inputs per hectare, i.e. fertilizers and pesticides, has increased substantially. However, although pesticides were once praised as yield savers, securing harvests in quality and amount (Richardson 1998), they only partly fulfiled expectations (FAO 2005).

Despite improvements in plant protection, the use of pesticides leads to a variety of unexpected negative effects on the environment (Lewis and Newbold 1997; Wilson and Tisdell 2001; De Jong and De Soon 2002; Kovach and Petzoldt 2004; Van den Brink and Crum 2004) and on human health (Amr 1999; IPCS 2001; Wilson and Tisdell 2001; Wessling, Corriols et al. 2005). Concerning environmental spillovers, pesticides are increasingly observed as depleting and contaminating important elements for agricultural production, like damaging soils and contaminating air and water (not only directly but also due to accumulation effects (Paterson and Mackay 1989)). Additionally, pesticides increasingly constitute a threat to biodiversity as pesticides do not only eliminate the targeted pests but also often have effects on other plants, insects or fungi that do not damage the crop. Furthermore other animal populations such as honey bees or earthworms have been observed to decline since the beginning of the green revolution (Emden and Peakall 1996). Moreover targeted pests are showing increasing resistance to pesticides (Wheeler 2002).

Pesticides have also been shown to have adverse effects on the health of producers and consumers of food. On the one hand producers are affected by applying highly toxic components without proper protection equipment. This inappropriate protection is particularly true for poor farmers who cannot afford less toxic compounds, proper application equipment and appropriate

personal protection (FAO 2005). Yet inappropriate protection also holds for wealthier farmers, calling into question their awareness of the health risks they expose themselves to (Swinton and Escobar 2003). On the other hand, consumers' health is affected by the consumption of contaminated foods (Zahm and Ward 1998; Ecobichon 2001).

Misuse of pesticide in developing countries relates to (i) lack of protection during the mixture (See Figure 1) and application procedure; (ii) inadequate storage facilities (iii) higher rate of application compared to industrialized countries; (iv) use of stronger products due to resistance of pest species (Chandrasekara and Wettasinghe 1985; WRI 1998; Wilson and Tisdell 2001).

Figure 1: Pesticide mixing with insufficient protection equipment. The chemicals used are frequently highly toxic and applied with little or no protective equipment.

Current studies have mostly focused on understanding which variables improve pesticide application behaviour. Land ownership and access to credit increase pesticide use (Rahman 2003), whereas education and wealth of farmers seem to have a considerable impact on reducing pesticide use or even on adopting integrated pest management practices (Chavez et al., 2001). Interestingly, pesticide use is reported to be significantly higher in less developed regions e.g. Asia and Africa (Rahman 2003) then in industrialized countries. In contrast, Swinton found that wealthier farmers, even though they had the financial capacity to invest in using pesticides more sustainably (less toxic pesticides, better equipment), did not do so (Swinton and Escobar 2003). They argue that farmers lack the incentives for performing good pesticide stewardship.

To conclude, there is no common explanation as to why farmers, especially small holder farmers in developing countries, continue to misuse pesticides. This thesis takes one step back and analyzes farmers' perception and reasoning about pesticides to better understand the basis of behaviour and decision making concerning pesticide use. Therefore, a first question is:

- How does farmers' perception of risks associated with pesticide application differ from the one of experts?

1.1.2 Mental Models Approach and Sustainable Livelihood Framework

An often-used attempt to analyze the subjective definition of risk is the Mental Models Approach (MMA) (Morgan, Fischhoff et al. 2002) based on Johnson-Laird's MMs of reasoning (Johnson-Laird 1983). The MMA is a method for understanding and analyzing reasoning and risk perception and was developed to improve risk communication between experts and laymen. MMA uses the knowledge of experts to understand the risks from a scientific point of view and compares it to the layman's subjective perception of a specific risk. The aim of the approach is to find possible communication failures revealed by misunderstandings or missing knowledge of laymen. In the final part of the approach, misunderstandings found are tackled by tailored information campaigns.

Small holder farmers in developing countries make decisions in risk situations not only by handling one risk at a time but through considering trade-offs among different risks. Several risks emerge in a person's decision which themselves are dependent on the situation the decision-maker is in. This perspective is neglected in the MMA and has not been analyzed before. Furthermore Morgan et. al. (2002) underline that the MMA is more a field guide and the method must be adapted to the particularities of the topic in question (Morgan, Fischhoff et al. 2002).

Several authors have emphasized that risk perception or risk strategies of small farmers in developing countries have to be studied in relation to their livelihood (Walker, Thorne et al. 1999; Gadgil, Seshagiri Rao et al. 2002; Orr and Ritchie 2004), even if the focus is only on specific risks such as environmental risks, e.g. soil erosion (Crole-Rees 2002; Quinn, Huby et al. 2003; Forsyth 2006).

Several methodologies for assessing farmers' livelihood have been developed by different research groups as well as international agencies (UNDP 1990; Chambers and Conway 1992; DFID 2001; Baumgartner and Högger 2004; de Haan and Zoomers 2005). In most of the methodologies, farmers' assets and capabilities are investigated through a set of participatory tools, like interviews and focus groups (Cramb, Purcell et al. 2004), leading to an assessment of the farmers' livelihood situation. One approach that has been developed to provide a more systematic and holistic perspective on farmers' livelihood-strategy selection is the Sustainable Livelihood Framework (SLF) (DFID 2001). The framework states that farmers' livelihood depends on their knowledge and ability to use their assets in such a way that the family can make a living, meet their consumption and economic needs, cope with uncertainties and respond to new opportunities (Appendini 2001; de Haan and Zoomers 2005). An important criticism of the SLF (DFID 2001) and related methods is that they assess farmers' livelihood from an expert's perspective, and neglect farmers' local knowledge and their view on their own livelihood. Even though research findings underline that farmers do have important system knowledge related to their livelihood, it is rarely included in the research on farmers' perception of pesticide application.

Considering the developments in research mentioned above, it can be concluded that in order to understand the risks related to pesticide use, in the context of small holder farmers in developing countries, the risks have to be studied in relation to their livelihood. Therefore, another open question in relation to pesticide use is:

- How does farmers' perception of their livelihood influence their risk perception?

The MMA, is an open approach which can be adapted to the problem under investigation, but which neglects the additional perspectives of farmers. The SLF, on the other hand, investigates farmers' livelihood as a whole but neglects farmers' own perception of their livelihood. Thus, combining the two approaches was one of the goals of the thesis. Therefore another research question the thesis investigates is:

- How can the MMA and the SLF be combined in order to compare experts' and farmers' perception of farmers' livelihood risks?

1.1.3 Future problems of pesticide use

In the future, additional factors have to be considered when analyzing agricultural development and including its effects on pesticide use. The most prominent factors are: 1) changing climate (IPCC 2007); 2) spread of pests throughout the world due to increased trade ("globalization") (FAO 2005); 3) changing agricultural markets reshaped by the demand for organic food and bio fuels (FAO 2005), and 4) changing agricultural technologies through an increase in the degree of mechanization or use of genetically modified plants (Borch 2007).

Considering the first point, climate change, and more specifically changes in summer and winter season, are likely to affect different parts of the world (IPCC 2007) with consequences for agricultural production in terms of both yields and threatening pests. With a change in temperature, rainfall and solar radiation, potato production, which critically depends on those elements, will decline (FAO 2005). Additionally climate change as a driver will have different effects on the various types of pests threatening the crop (FAO 2005). Base studies of individual species show that climate change impairs pest developmental rates and numbers of pest generations per year, pest mortality due to cold and freezing during the winter months, or host plant susceptibility (Dangles, Carpio et al. 2008).

Considering the second point, pests from other parts of the world are likely to spread with increasing open trading markets and increasing human movement. There are "established pests"

which are ecologically adapted to a certain area of the world and not distributed everywhere. This is likely to change in the future, especially with increasing agricultural trade and transport as well as tourism and migration. Examples like the spread of soya rost and polilla guatemalteca occur (FAO 2005; Dangles, Carpio et al. 2008) even despite the efforts of regional plant protection organizations to limit the introduction and spread of pests in their territories.

In summary, the understanding of farmers' perception of future pesticide application will become even more important, considering the future challenges which farmers will have to confront. Farmers, especially in less developed regions, seem to be unaware of this effect as they continue to misuse pesticides in spite of an observed deterioration of their means of subsistence (Rahman 2003; Swinton and Escobar 2003). Thus an additional question concerning pesticide use is:

- How does farmers' vision for their future and their future pesticide use differ from the one of experts?

Furthermore, as presented above, farmers will have to adapt to changing conditions and will have to learn how to confront new pests and how to adapt the known techniques in pesticide use to the new conditions. Their ability to adapt to these new circumstances will depend on their livelihood structure, their sensitivity to future changes and their knowledge biases reflected in their MMs. Thus, comparable to the research question related to the influence of farmers perceived livelihood on farmers' perception of present pesticide use, the following research question emerges:

- How does farmers' perception of their livelihood influence farmers' future visions concerning pesticide use?

Although the influences of past and present MMs on the construction of future MMs have been analyzed and critically discussed by different researchers in the field of Future Studies (Bell and Mau 1971; Ingvar 1985; Ono 2003; MacKay and McKiernan 2004; Lynam, De Jong et al. 2007) the comparisons remain general in nature. Moreover, none of them compares the logic of MMs of a specific problem, such as pesticide use, in the present and the future. This suggests that there is a need to define the actual mechanism of dependence of future on present MMs especially for the case of pesticide use. Therefore the final research question of this thesis is:

- How can farmers' perception of the present situation and farmers' future visions be compared and what kind of information can be gained from such a comparison?

In summary, this thesis concentrates on investigating the reasoning behind the misuse of pesticides by considering MMs, livelihood influences and future visions of farmers.

1.2 Structure of the thesis, research goals and questions

The main objective of the thesis is to derive and understand the reasoning behind the use of pesticides in the present and in the future. To reach this objective the PhD thesis is organized in four parts (see Figure 2). Each of the parts focuses on one research goal and research questions related to that goal. From each of the parts one peer-reviewed publication emerged.

Part one focuses on deriving a method to compare experts' and farmers' MMs of farmers' livelihood. Part two focuses on analyzing farmers' risk perception concerning pesticide use by comparing it to experts. Part three focuses on deriving the basis of farmers' visions concerning future pesticide use. Finally, part four compares the findings of part two and three.

This thesis is composed of the following four peer-reviewed publications:

i. Binder, C.R. and Schoell, R. 2010. Structured Mental Model Approach for Analyzing Perception of Risks to Rural Livelihood in Developing Countries *Sustainability (Vol.2, pp. 1-29; doi:10.3390/su2010001)* [Paper 1]

ii. Schoell, R. and Binder, C.R. 2009. System Perspectives of Experts and Farmers Regarding the Role of Livelihood Assets in Risk Perception: Results from the Structured Mental Model Approach. *Risk Analysis (Vol. 29, No. 2, pp. 205-222)* [Paper 2]

iii. Schoell, R. and Binder, C.R. 2009. Comparing system visions of farmers and experts. *Futures (Vol. 41, No. 9, pp. 631-649)* [Paper 3]

iv. Schoell, R. and Binder, C.R. 2010. Comparison of farmers' mental models of the present and the future: A case study of pesticide use. *Futures In press doi:10.1016/j.futures.2010.04.030* [Paper 4]

Author's contributions

In the first paper both authors contributed equally to the manuscript of the paper. Under the guidance of the second author the contribution of the first author increased throughout the process of papers two, three and four. The contributions of the first author were, 70% in the second, 80% in the third and 90% in the last paper. This means that for the second, third and fourth paper the first author collected and analyzed the data as well as conceptualized and wrote the papers whereas the second author contributed significantly on the introduction and discussion sections, overall structure, writing and style.

Part one

Paper 1

Goal:
Develop an approach to compare farmers' and experts' mental models of farmers' livelihood.

Research question:
- How can the MMA and the SLF be combined in order to compare experts' and farmers' perception of farmers' livelihood risks?

Part two

Paper 2

Goal:
Compare farmers' and experts' mental models of farmers' livelihood with a special focus on pesticide application.

Research questions:
- How does farmers' perception of risks associated with pesticide application differ from the one of experts?
- How does farmers' perception of their livelihood influence their risk

Part three

Paper 3

Goal:
Compare farmers' and experts' mental models of farmers' future livelihood with a special focus on pesticide application.

Research questions:
- How does farmers' vision for their future and their future pesticide use differ from the one of experts?
- How does farmers' perception of their livelihood influence their future visions

Part four

Paper 4

Goal:
Develop an approach to compare farmers' present and future mental models of their livelihood.

Research question:
- How can farmers' perception of the present situation and their future visions be compared and what kind of information can be gained from such a comparison?

Figure 2: Overview of research questions and goals handled in each of the thesis' peer-reviewed publications.

1.3 Frame of the PhD thesis

This PhD thesis is an important pillar of an overarching project titled: “Reducing human health and environmental risks from pesticide use: Integrating decision-making models with spatially explicit dynamic risk assessment (Case study: Vereda la Hoya, Tunja, Colombia)”. The project is being performed in cooperation with UNIBOYACA, with whom Prof. Dr. Claudia R. Binder, Head of the Unit Social and Industrial Ecology, has being pursuing a research partnership since 1992.

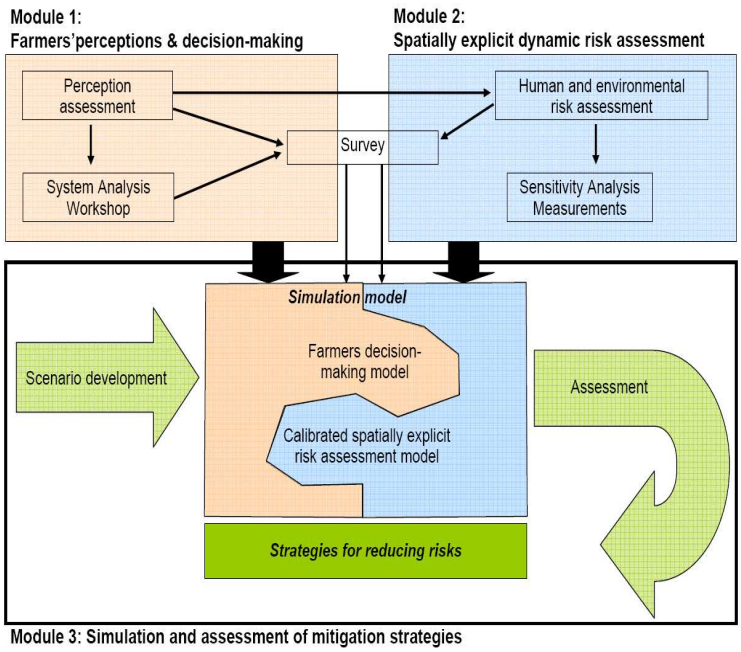

Figure 3: Overarching project overview

The overarching project (project overview see Figure 3) aims at building a simulation model combining farmers’ perceptions and decision-making (pink color) with spatially explicit dynamic risk assessment of farmers’ pesticide use (blue color). The thesis presented here contributes to the build-up of a behavioral model of farmers’ pesticide management (Module 1), by analyzing the farmers’ MMs.

This thesis was started in January 2005 at the ETH under the supervision of Prof. Dr. C. R. Binder. Writing up and processing of the data were done from May 2006 onwards at the University of Zurich. Figure 4 shows the organizational structure of the project. The Swiss company Syngenta, one of the world leading producers of pesticides financed the thesis.

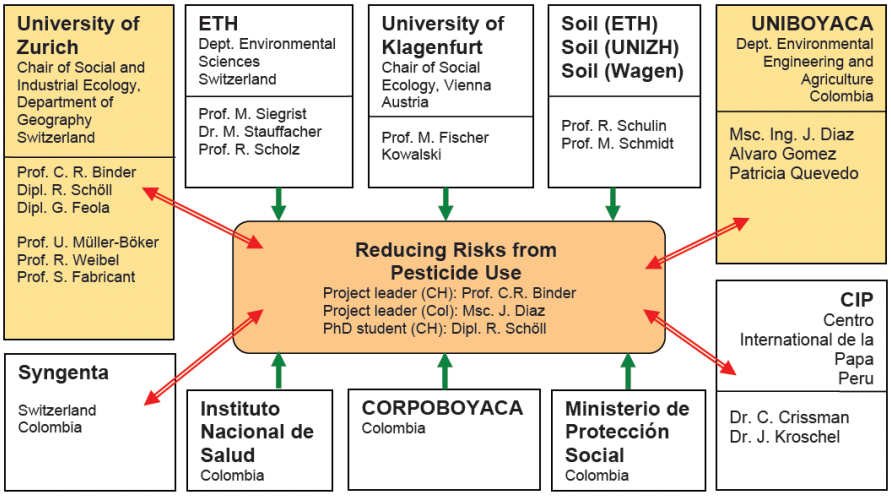

Figure 4: This overview of the organizational structure also includes the PhD thesis.

2 Theoretical background

In the following, an overview of the theoretical concepts of the SMMA are given, including MM, decision-making theory, social structural theory and theories of farmers' livelihood assets. All these theories serve as a basis for the SMMA and lead to the combination of the Mental Models Approach (MMA) and the Sustainable Livelihood Framework (SLF).

2.1 Theoretical bases for constructing the SMMA

Pesticide application manners are regarded, on the one hand, as the results of psychological cognition processes (consisting of MM and decision-making), and on the other, as influenced by socio-cultural boundary conditions (consisting of culture and livelihood assets). The SMMA covers both perspectives. The conceptual framework of the SMMA is illustrated by Figure 5 and different elements of the figure are explained in more detail in the following sections.

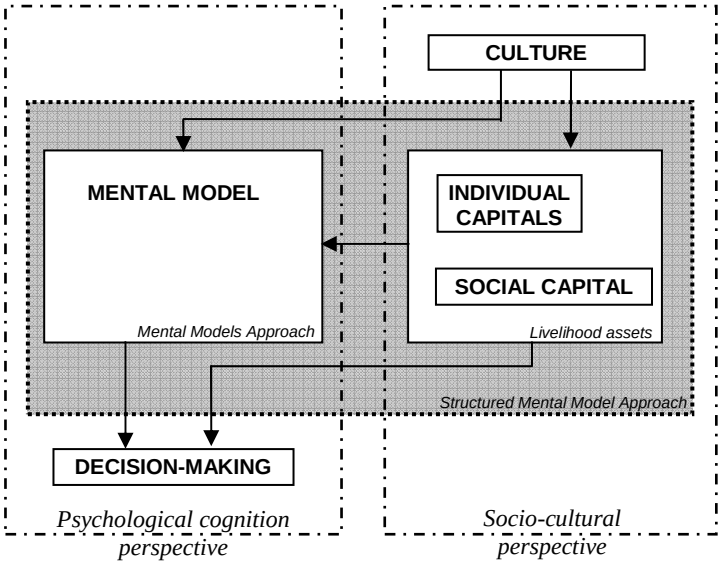

Figure 5: SMMA theoretical framework: Combining the psychological cognition perspective and the socio-cultural perspective.

2.1.1 Psychological cognition perspective

According to psychological theories, decision-making is seen as the cognitive process leading to the selection of an action among various options (Jungermann, Pfister et al. 2005). In cognition theory there are different theories about how cognitive processes are structured. In our case the cognitive process related to pesticide use was divided into two consecutive steps: MMs and decision-making.

MENTAL MODELS

To explain reasoning as one part of a cognitive process the MMs as described by the theory of Philip N. Johnson-Laird (1983) was used. According to Brunswiks' cognition theory (Brunswik 1952) it is not possible to perceive an object or an event directly. It is only possible to construct internal representations, so called MMs, of real objects and events from sensory information (Brunswik 1952). Johnson-Laird (1983) investigates human reasoning using the theory of MMs, which are models of someone's reasoning about how something works in the real world (Johnson-Laird 1983). MMs have been examined in many different domains ranging from physics students' intuition about mechanics (di Sessa 1988) to indigenous people's typologies of the natural world

(Atran 1990), people's reasoning about system dynamics (Doyle and Ford 1998), and people's processing medical information from package inserts (Jungermann, Schütz et al. 1989).

The facts that someone knows and reasons about by means of his MM can be certain (e.g. pesticides kill pests) or uncertain (e.g. pesticides may kill around 30% of the pest infestation) (Brunswik 1952). For example a persons' MM of a plant can include the fact that plants need sunlight to survive and to grow but also uncertain assumptions such as how many days a plant can live without sunlight. Some processes and the MMs of those processes can contain reasoning about risks (e.g. the use of pesticides represents a risk to the health of a farmer applying pesticides without protective equipment), whereby again in the definition of risk there are MMs containing facts which are uncertain.[1].

In the case of cognitive processes related to pesticide use, the MMs serving as a basis for making decisions concerning pesticide use are therefore MMs related to risks. According to the definition of risk, MMs of pesticide use are MMs of processes containing facts with some degree of uncertainty.

Uncertain mechanisms in MMs that their users are aware of can be mitigated by looking for further information. For example, in the case of pesticide use the uncertainty a person has about health risks can be mitigated by looking for safety information.The limits and quality of information acquisition is one of the main aspects of risk communication (Morgan, Fischhoff et al. 2002).

Beside education and informational campaigns about facts relating to pesticide use, other mechanisms such as personal experience and social rules also influence the MMs of pesticides. In the case of risk perception, concerning risks related to pesticide use, the assumptions and inference methods of intuitive toxicology have been shown to influence farmers' MMs of pesticide use (e.g. smelly pesticides are more toxic than non smelly pesticides) comparable to findings of Slovic demonstrating how intuitive toxicology influences smokers' decisions to smoke (Slovic, Finucane et al. 2004).

A way of understanding laymen MMs of risk related processes (including effects of personal experience and social rules) is to compare laymen's MMs with experts' MMs. Morgan and Fischhoff (2002) introduced the Mental Models Approach (MMA) as a tool for analyzing risk-communication issues. The MMA compares risk-information from the providers (experts) and users (laymen) in order to reveal informational gaps or misunderstandings. The MMA and similar approaches has been applied to different areas of research e.g. climate change (Bostrom, Morgan et al. 1994), electric and magnetic fields (Bostrom, Morgan et al. 1994), the World Wide Web (Yan 2008), water management (Kolkman, Kok et al. 2005), and nuclear energy sources (Maharik 1992). Morgan and Fischhoff (2002) conclude that these misunderstandings are the main cause of irrational risk-decisions.

DECISION-MAKING

MMs form the basis for problem solving and decision-making (Gigerenzer, Hoffrage et al. 1991), therefore the consecutive step of MM in the SMMA theoretical framework is decision-making (Figure 5). Decision-making for small-holder farmers in developing countries refers to every day decisions that are related to a risk, either for their livelihood or for the environment. Decision-making theory classifies decisions by type and degree of cognitive effort into five classes: routine decisions, stereotype decisions, parallel differentiation in the analysis of decision error, constructive decisions and reflective decisions (Jungermann, Pfister et al. 2005). Decisions are

[1] In the risk related literature there is a great diversity of definitions of risk (Wilson and Crouch 1982; Kates and Kasperson 1983; Short 1984; Dietz, Frey et al. 2002). In this thesis the definition of Pidgeon and Kasperson (2003) was mainly used. Most definitions of risk have three elements in common: they always include 1) some state of reality of human concern or interest that is at stake, 2) an outcome that is possible, and 3) uncertainty about the outcome. One of the most comprehensive definitions is that of Pidgeon and Kasperson (2003). They define risk to be a situation or an event where something of human value (including humans themselves) is at stake and where the outcome is uncertain. For the case of pesticide misuse the thing at ***stake*** is farmers' environment and human health. Following Pidgeon and Kasperson's definition, what is ***possible*** is that health and environment may be damaged by the use of pesticides and what is ***uncertain*** in applying pesticides is that farmers do not know the degree their environment or health will be damaged from misuse of pesticides.

classified as reflective when they are based on MMs. We consider the people making pesticide related decisions as reasoning individuals. Therefore in the case of pesticide management, we will look at decisions concerning pesticide application as being reflective decisions. Moreover in reflective decisions risks are regarded as consequences which decision makers considered before making the decision[2].
Furthermore this thesis focuses on decisions farmers make related to risks that farmers confront in an active way, i.e. risks that farmers can decide to take or not to take (considering the pros and cons of a decision). Farmers' awareness of the risks they confront is also reflected in their MMs.

Farmers in developing countries are confronted with several types of risks related to the decisions they make affecting their livelihood (Yung 1992; Crole-Rees 2002). Therefore the reasoning process of a person is understood as the weighting of the different risks within farmers' livelihood. Based on his MM the risks are weighed up and the person makes his decision.

2.1.2 Socio-cultural perspective

In the following the important aspects of the socio-cultural perspective considered in this thesis are explained. These are culture (representing the norms, rules and values of a social group) and the livelihood assets of a person (representing the human, physical, financial, natural capital and social capital).

CULTURE

In the framework of this thesis the culture a person is embedded in is defined as the norms, rules and values[3] of that person's social group. Norms, rules and values influence a person's MMs, as social norms and rules determine some of the mechanisms that can be found in MMs (e.g. spiritual believing). Furthermore the culture influences the livelihood assets of a person making a decision related to a risk, e.g. depending on rules and values, different livelihood assets are perceived and used differently by a person (Triandis 1980; Giddens 1984; Giddens 1994).

LIVELHOOD ASSETS

The livelihood assets used in the framework are adapted from the Sustainable Livelihood Framework SLF (see Figure 5) (DFID 2001). The SLF has been developed to provide a more systematic and holistic perspective on farmers' strategy selection. The framework states that farmers' livelihood depends on their knowledge and ability to use their assets in such a way that the family can make a living, meet their consumption and economic needs, cope with uncertainties and respond to new opportunities (Sen 1989; Appendini 2001; de Haan and Zoomers 2005). Typically, human capital, physical capital, financial capital, natural capital and social capital are considered when studying farmers' livelihood (DFID 2001). The stock of capitals is specific for each farmer, constraining or enabling his/her decisions and actions (Orr and Ritchie 2004). The results from livelihood analysis have been used for evaluating and developing sustainable rural development programs on a micro level (UNDP 1990; Chambers and Conway 1992; DFID 2001; Cramb, Purcell et al. 2004; de Haan and Zoomers 2005).

The livelihood assets which influence the MMs of farmers are included in the framework as a way of structuring farmers' livelihood. In contrast to the SLF, in this thesis the livelihood assets are divided into the individual capitals (human, natural, physical and financial capital) and social capital (Scoones and Thomson 1994).

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[2] In research other factors were also found to influence the decisions farmers make, e.g. routines. This different kind of decision base was investigated by another member of the research group and is therefore part of another PhD thesis.

[3] The actual "value" of a capital depends on the rules of the social group. For example the "value" of health depends on how valuable health is regarded inside a society.

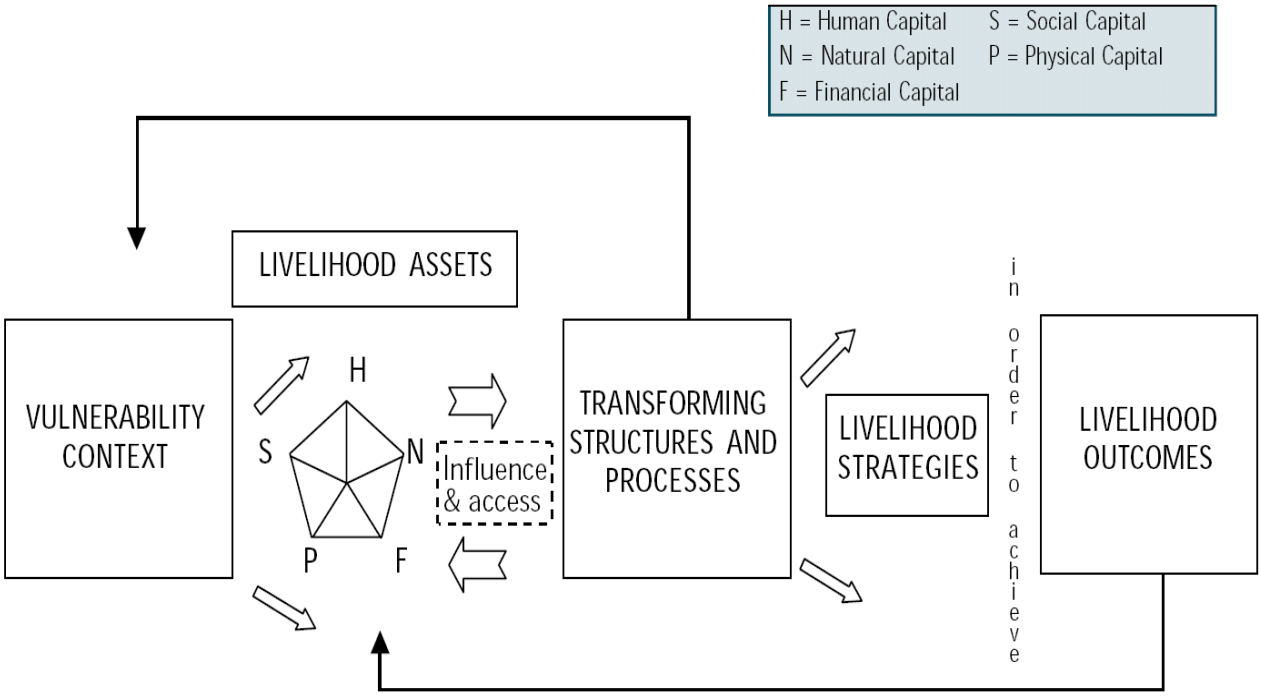

Figure 6: DFID Sustainable Livelihood Framework (SLF) (DFID 2001)

When reasoning about pesticide use, farmers consider not only what they know about pesticides, but also weight different aspects of their livelihood against consequences of the use of pesticides. Therefore not only do MMs of pesticide use have to be considered but also MMs of farmers' livelihood and the role of pesticides in it. Depending on farmers' financial possibilities, certain pesticides may not be purchasable, or additional time-consuming procedures be not be feasible, or cultural aspects like taboos may inhibit the uptake of new pesticide usages. Therefore farmers' livelihood assets influence on the one hand farmers' MMs and, on the other, farmers' decision-making (see Figure 5). Additionally, as explained above, farmers' MMs are used by farmers to make decisions. The possible options and the entire frame of what is at stake provides additional explanations as to why a specific decision concerning a specific argument is taken. Therefore an important cornerstone of this thesis is to consider farmers' livelihood and local knowledge, which both influence farmer decision-making.

2.1.3 Combination of MMA and SLF to SMMA

The theoretical basis of the SMMA is illustrated in Figure 5 as a combination of the previously discussed psychological cognition perspective and the socio-cultural perspective.

The psychological cognition perspective was addressed in two steps: MMs and decision-making (see left side of Figure 5). The MMs explain reasoning via the definition of Johnson-Laird's MMs (Johnson-Laird 1983), and are investigated with the MMA of Morgan and Fischhoff (2002). Furthermore, we call decision-making the step after the reasoning-process, as it is influenced by MMs and by the current livelihood assets of a reasoning farmer.

The right hand of Figure 5 illustrates how the socio-cultural perspective is treated and how the social-cultural factors influence the steps of the cognition process. A person's weighting of risk-alternatives is considered to be influenced by livelihood components. A person's individual capitals and social capital represent the livelihood components determining the options considered in each decision-making process with the help of MMs. For example, the character of a person (e.g. an element of a person's human capital) influences to what degree (in quality and quantity) facts can be incorporated into the MM (what kind of facts and from how many and what kind of sources of information). Furthermore the character of a person can influence the perception and the judgment

of a risk, for example if an amount of risk is high or low (people can be risk-taking or risk-averse). Moreover the framework considers that a person's culture (representing the norms, rules and values of a social group) influences a person's MMs as well as the livelihood assets of that person (Giddens 1984).

Even though a risk does not change through a person's perception of it, a decision entailing a certain risk as a consequence is determined by how the risk is perceived (i.e. a decision concerning a certain risk depends on how and whether the risk is realized) (Slovic, Finucane et al. 2004). Furthermore, wherever different options or attributes are considered the perception of those other options and the weighting of the options in comparison to each other will additionally influence the decision-making process.

Finally the framework regards livelihood assets as also influencing a person's decision-making directly by somehow constituting boundary conditions of a decision, e.g. farmers cannot decide about livelihood assets they do not possess.

On the basis of the combination of psychological cognition perspective and socio-cultural perspective presented above the Structured Mental Model Approach (SMMA) was developed. The SMMA uses the MMA and structures it by means of the SLF (Figure 7). It allows for deriving experts' and farmers' MMs of farmers' livelihood assets and reveal trade-offs among farmers' livelihood assets.

Concept of comparing experts and laymen mental models derived from the MMA

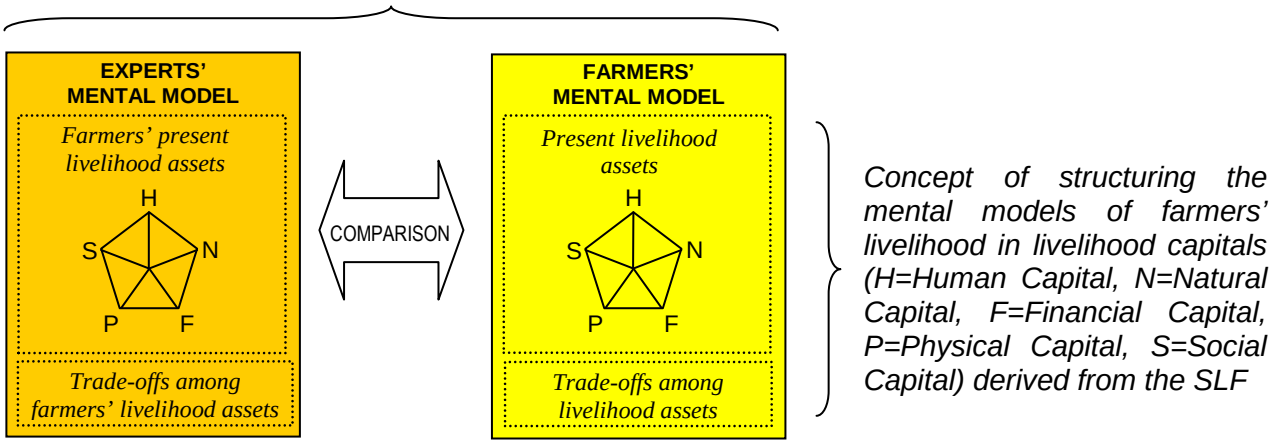

Figure 7: How the Structured Mental Model Approach combines the Mental Models Approach (MMA) and the Sustainable Livelihood Framework (SLF)

The concept of combining the MMA and the SLF was additionally fostered by the following ideas. Experts clearly differ from farmers in the way they define risk. Experts view risk as the probability of an adverse event (e.g. injury, disease, death) times the consequence of that event (e.g. number of injuries or deaths, types and severity of diseases) (Wilson and Crouch 1982). Experts therefore take an objectivist view of risk. In contrast, farmers have a subjectivist view. As with most extreme positions, the objectivist and subjectivist views of risk, taken separately, are poor descriptions of reality (Short 1984; Dietz, Frey et al. 2002); therefore in this thesis those two views of risk were compared in order to achieve a more complete description of reality and to find new insights concerning the pesticide application problem.
To manage this task the objective experts' view of risk and the subjective farmers' view were compared. This required projecting the experts' objective view onto the livelihood context of farmers and therefore including in the analysis not only experts on the pesticide health risk issue but also experts on farmers' livelihood in general or experts on other topics of farmers' livelihood, such as medical doctors. Furthermore it demands investigation not only of farmers' views on the

specific risk (in this case pesticide) but of what farmers think about their livelihood and about experts telling them about certain security measures. By combining experts' and farmers' perspectives an enlargement of common system understanding and a more holistic view of the problem resulted, which supports the development of policies concerning pesticide use on a clearer and more amply ground.

2.2 Theoretical bases for constructing the Future-SMMA

The aims of decisions, the feedback of future desires on present MMs and mechanisms of deduction from present to future MMs were investigated by analyzing future MMs. This constitutes the theoretical basis for part three and four of the research conducted in this thesis. How the effects of analyzing future MMs constitute the bases for the Future-SMMA is illustrated in Figure 8.

The future perspective of a decision represents the consequences someone expects. Expectations are derived from present experiences and reasoning about cause and effect. Therefore future perspectives of an issue can give valuable indications about what kind of possible effects a person derives from the present to happen in the future (Blackman and Henderson 2004). The MM of a person therefore also influences his expectations for the future and therefore his MM of the future(see influence of MM on Future MM in Figure 8).

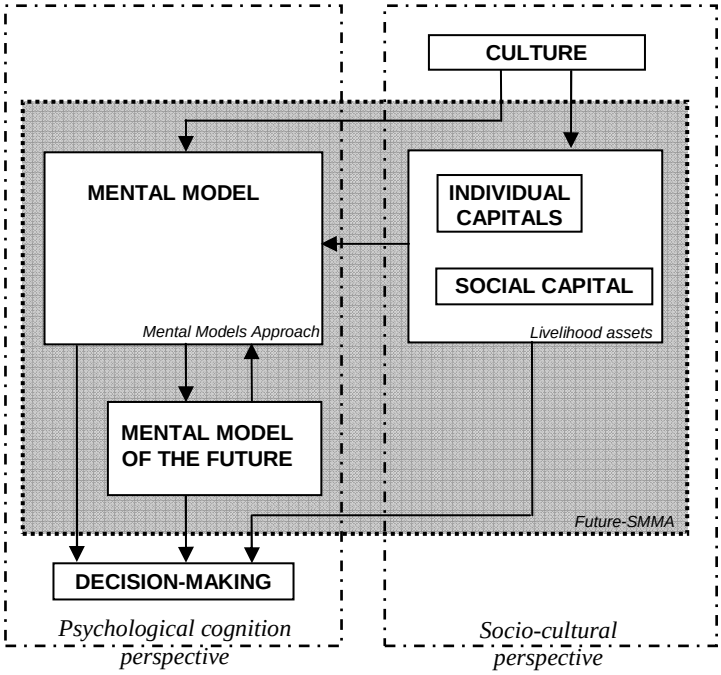

Figure 8: The future-SMMA theoretical framework is based on the SMMA and additionally considers the role of mental models of the future. Thus, influences of mental models of the future are of special interest.
Farmers' mental models influence farmers' mental models of the future. Moreover farmers' mental models of the future influence farmers' present decision-making by representing the aims of farmers' decisions. Additionally farmers' mental models of the future influence farmers' present mental models by enhancing farmers' desires for the present.

However there are also desires that go beyond what a person perceives in the present, things they hope for in the future which influence their decisions and what they reason in the present. Scenario planning has been defined by Chermack and Lynham (2002) as "a process of positing several informed, plausible and imagined alternative future environments in which decisions about the future may be played out, for the purpose of changing current thinking, improving decision making, enhancing human and organization learning and improving performance". Moreover according to Future Studies the analysis of future desires reflects the reasoning of a specific decision (Blackman and Henderson 2004).

Decision-making theory structures decisions in several components, one of the most important being "aims of the decisions" (Jungermann, Pfister et al. 2005). Therefore farmers' MMs of the future influence farmers' decision-making by representing the aims of farmers' decisions. In the case of pesticide decisions the aims of pesticide application are related to intentions linked to MMs of future agricultural production (see Figure 8).

The scenario planning effect on changing current thinking (Chermack 2006) is represented in the framework of the Future-SMMA as the effect of future MMs on present MMs (see Figure 8: influence of future MM on present MM). The scenario planning effect on improving decision making (Chermack 2004) and future desires being aims of decisions (Jungermann, Pfister et al. 2005) are represented in the Future-SMMA as the effect of future MMs on decision making (see Figure 8: influence of future MM on decision making).

Finally the effect of present on future MMs analyzed in this thesis is based on the following theoretical concepts. Engel et al. (1968) define problem recognition as occurring when a consumer recognizes a difference of a significant magnitude between what is perceived as the desired state of affairs and what is perceived as the actual state of affaires (Engel, Kollat et al. 1968; Brush, Clemes et al. 1997). Moreover depending on the accuracy of their present and future MMs, decision-making errors can occur leading to health and environmental damages (Morgan, Fischhoff et al. 2002), such as neglect of protective equipment and overdosage of pesticides. By studying and comparing farmers' present and future MMs the accuracy of future MMs is analyzed. Therefore, to find further drivers for unreasonable pesticide use the present and future MMs of farmers were compared.

3 Research design and methods

3.1 Design

The research was conducted in four parts as illustrated by Figure 9.
Part one constitutes the theoretical basis of the developed SMMA and Future-SMMA to analyze the pesticide problem in the study area. During the conduct of this part the theoretical basis of MMs and the livelihood framework were acquired and combined to develop the SMMA and Future-SMMA. Thus in this part the procedural steps of the interview such as the sequence in which the experts and farmers were interviewed, and the structure of the interview itself, were defined.
In part two, the SMMA was applied in the study area focusing on the pesticide problem. The interview subjects (experts and farmers) were chosen and the generally defined SMMA adapted to the pesticide application problem. After the SMMA interview session was concluded, a workshop was held to obtain a common system understanding between experts and farmers.
In part three, the Future-SMMA was applied in the same study region as the SMMA. To derive the desired pesticide application of farmers the SMMA was adapted to the future time frame with two important consequences. First, the farmers had to be interviewed first and the experts' interviews had to be constructed in terms of the results obtained from the farmers' interviews. Second, the open-ended questions were reformulated to assess the dynamic relation of a possible expected future. Following this second interview session in the study area a future workshop was conducted to obtain a common future system view among experts and farmers.
In the fourth and final part, the data obtained from the two previous interview sessions were compared and conclusions concerning the dependence in reasoning of future from present MMs concerning pesticide application were derived.

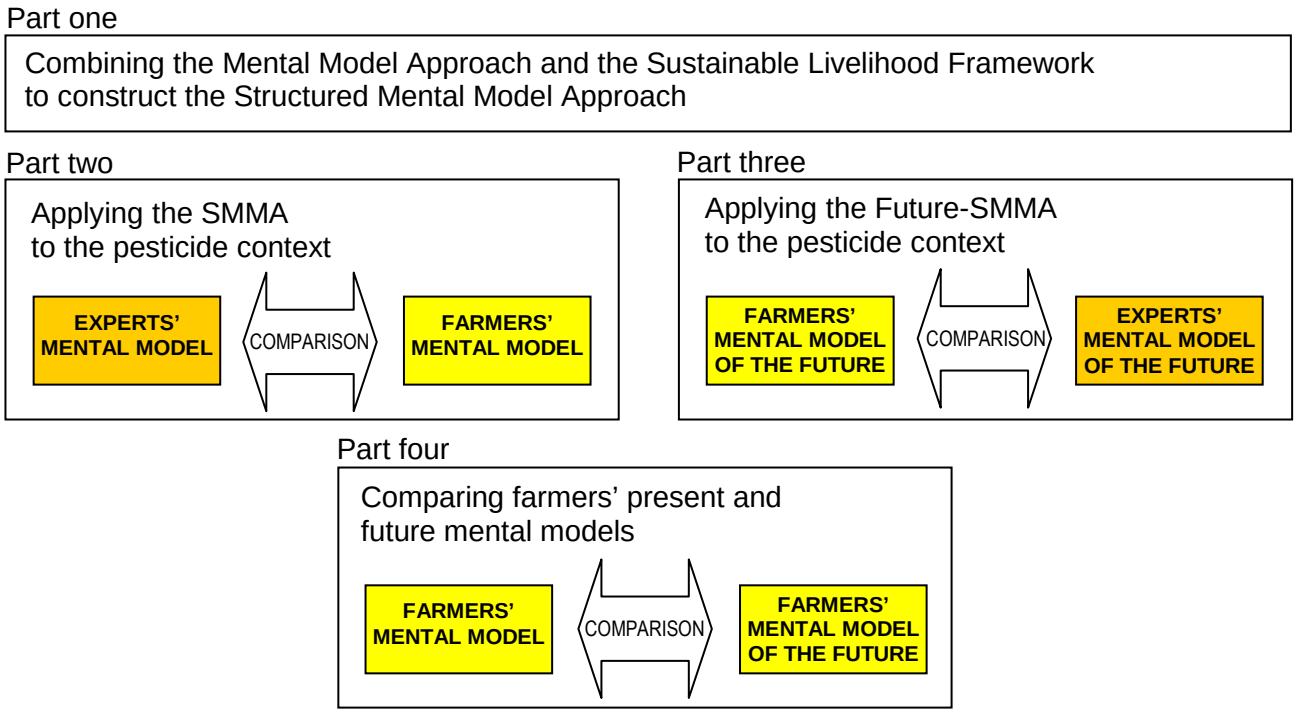

Figure 9: PhD thesis design, also illustrating the order in which the different mental models were obtained.

3.2 Study area

The selected study area Vereda la Hoya (see Figures 10 and 14), is located in the rural part of the municipality of Tunja in the Departamento de Boyacá (Colombia) (see Figure 11). La Hoya ranges from 2700 to 3250 m.a.s.l. over an area of 840 ha, has an average temperature of 12℃, and a

Figure 10: Study region Vereda La Hoya viewed from Puente de Boyacá

population of about 750 inhabitants. The main source of income is farming. Farmers cultivate in "minifundios" of an average size of 6.6ha (Buitrago and Alvarado 2000; POT 2000). The land use pattern is: crop production 40%, animal husbandry 25%, fallow land 33%, and forest 2%. The main agricultural products grown in La Hoya are: potato 27%, vetch (carrots) 23%, corn 18%, horse bean 18%, wheat 9%, and onion 5%. The land is cultivated in two cycles a year (September to February and March to August), which permits two harvesting seasons, February and August. The typical rotation consists of 2-3 cycles of potatoes, 1-2 cycles of carrots, and 2-4 cycles of fallow land. Potato production in la Hoya is vulnerable to three major pests, the soil-dwelling larvae of the Andean weevil (Premnotrypes vorax, "Gusano blanco"), the late blight fungus (Phytophthora infestans, "Gota"), and Guatemalan potato moth (Tecia solanivora, "Polilla Guatemalteca"). For the control of these pests both farmers and agricultural scientists consider the use of both insecticides and fungicides, such as carbofuran, mancozeb and methamidophos, necessary (Senanayake and Karalliedde 1987; Baron 1991; Edwards, Ferry et al. 1991; PAN 2004; Extoxnet 2005). For further detail see the publications in the appendix.

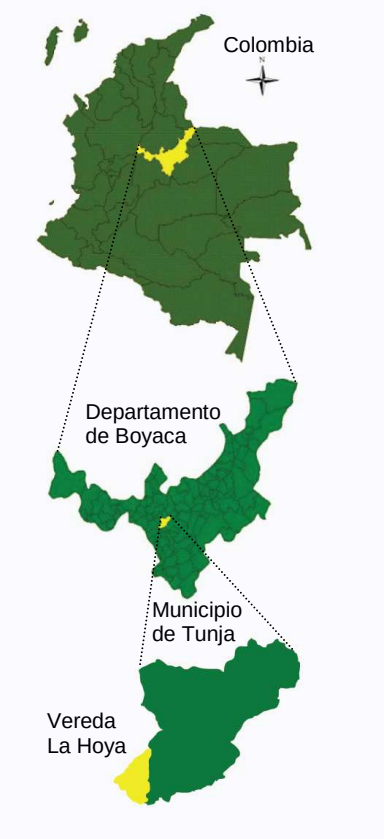

Figure 11: Overview of geographical and geopolitical placement of the study region

3.3 Sampling

The experts had to be important agents for the farmers and/or have experience with pesticide management issues. The chosen experts of the study included governmental technicians providing farmers with technical support, health related entities like local doctors, as well as key pesticide sellers and retailers in the region.

Farmers were chosen by purposeful sampling (Wittokowski 1994; Atteslander 2008) from the farmers living and farming potatoes in the study region. The complete set of farmers participating in the interview sessions were chosen to cover all different levels of livelihood composition, measured by the five livelihood capitals (human, health, natural and financial capital) constituting the characteristics of farmers' livelihood and the pesticide application problem. That is, farmers were chosen to have a high or low level of each of the livelihood capitals investigated, e.g. having a good social status in the community of farmers (high social capital) or low creditworthiness (low financial capital).

3.4 Interview sessions

Two interview sessions (see Figure 12) and two workshop sessions (see Figure 13) were conducted. As shown in Table 1 some study subjects participated in all four sessions, others only in one. Some of the interviewed farmers had additionally participated in other workshops also held in the region.
Both interview sessions were conducted within a two-month period. As illustrated in the PhD design for the conduct of the SMMA, experts were interviewed first and farmers' interviews were based on the experts' interviews. The chosen experts were thereby seen as the main informants to the farmers concerning pesticide application. In contrast to that, in the Future-SMMA, the farmers were interviewed first and consequently the expert interviews were based on the farmers' interviews. Concerning future visions, farmers were seen to be the main drivers of their own future and were therefore chosen as a starting point for the interviews.

Table 1: Overview of two interview sessions (middle) and two workshop sessions (right) performed during the completion of the thesis.

Timeframe [execution year]	**Method [# of participating farmers] / [# of participating experts]**	
	Mental Model Interviews	Formative Scenario Analysis Work Shops
Present [2005]	SMMA [10] / [13]	System Analysis and Impact Analysis [9*+2] / [7]
Future [2007]	Future-SMMA [7*+3] / [10*+3]	Scenario Construction and Consistency Analysis [9**+2*+3] / [5**+4]

* = participated also in the SMMA
**= participated also in the Future-SMMA

Figure 12: Farmer interview

Figure 13: Workshop with farmers and experts

3.5 Additional work

Complementing the interviews and combining the first two parts of the PhD thesis, the workshops held during the study consisted in deriving and assessing a set of strategies for reducing human health and environmental risks from pesticide use and thereby improving farmers' livelihood within economic and social agricultural constraints.
In order to achieve this aim participatory methods were applied. Transdisciplinary work shops are used to incorporate local stakeholders in the analysis of complex stakeholder driven systems. A system analysis workshop (2005) and a scenario construction workshop (2007) were conducted (see Table 3), both being part of the Formative Scenario Analysis method (Scholz and Tietje 2002). The workshops were conducted by assuming that it is possible to derive a common system-understanding as well as a common future view on system dynamics (starting from the farmers' / experts' MM evaluation) Submitting the latter to a backward planning process, strategies for improving pesticide application can be developed.
The participants of the conducted workshops were the farmers and experts who participated in the SMMA and the Future-SMMA. The workshops took place after each of the interview sessions.
A further publication presenting the combined results of the two workshops is in preparation.

Furthermore research for three Master's theses was carried out during this PhD thesis in the same study region with the aim of partly adding to the derived information or partly validating the research findings. The thesis of Leuenberger consisted of an environmental pesticide fate assessment model and the evaluation of a survey performed in the study region (Leuenberger 2005). Seitlinger applied the Response Inducing Sustainability Evaluation (RISE) tool with the farmers participating in the PhD study (Seitlinger 2006). Baumberger conducted an ethnological thesis on the pesticide problem in the study region (Baumberger 2008).

One Master's thesis was based on another study region. The SMMA was adapted by Mosimann to evaluate the impact of the introduction of a new crop to a maize bean cultivation system in Nicaragua (Mosimann 2009). Based on her experience a manual for the SMMA was developed (see additional publications).

Moreover the SMMA was applied to a comparative group of farmers being intervened by a pesticide-selling company and effects of their intervention could be traced (a report is in progress, see additional publications).

Figure 14: View of the study region from its highest peak (towards Puente de Boyacá)

4 Summary of the papers

4.1 Paper 1

Structured Mental Model Approach for Analyzing Perception of Risks to Rural Livelihood in Developing Countries
Journal: *Sustainability (Vol.2, 2010, pp. 1-29; doi:10.3390/su2010001)*
Authors: Binder, C.R. and Schoell, R.

4.1.1 Motivation and research goals

This first publication of the thesis represents the theoretical basis for the thesis by presenting the background and the construction of the SMMA. It emphasizes how the approach bridges the psychological cognition theory with the socio-cultural theory overcoming so far omitted research gaps.

Small-holder farmers in developing countries are confronted with several types of risks affecting their livelihood (Yung 1992; Crole-Rees 2002). Some of the risks farmers take could be mitigated by improvement of information about the risks or by policy recommendations for avoidance of the risk. Some others consist of trade-offs between different risks which can only be weighted in relation to each other. Several attempts to directly or indirectly mitigate those risks failed. First because the risks were not assessable in its complexity (in the frame of all risk alternatives), second because detected risks failed to be effectively communicated to the people facing the risk. It is expected that disregard of risk perception could be one of the factors driving the increasing problems. Several authors have emphasized that the risk perception or risk strategies of small farmers in developing countries have to be studied in relation to their livelihood even if the focus is only on specific risks such as environmental risks, e.g. soil erosion (Walker, Thorne et al. 1999; Gadgil, Seshagiri Rao et al. 2002; Quinn, Huby et al. 2003; Orr and Ritchie 2004). Therefore based on risk communication theory this paper states that in order to reveal communication failures, which are expected to cause inappropriate/unsustainable environment management practice, it is important to consider risk perception (MMs about a certain risk) as well as risk trade-offs related to the analyzed environmental management problem.

Several methodologies for assessing farmers' livelihood have been developed by different research groups as well as international agencies (UNDP 1990; Chambers and Conway 1992; Baumgartner and Högger 2004; de Haan and Zoomers 2005). However the concepts and the developed methodologies such as the Sustainable Livelihood Framework (SLF) (DFID 2001) have neglected two important aspects in the assessment of farmers' livelihoods so far: 1) Local knowledge and self-perception of farmers, from which they draw their conclusions and balance their risks, and in which they embed their decision-making; and 2) the specific role of social capital in particular, the differences of how experts see the social network farmers are embedded in and how farmers see themselves as well as the consequences of these differences for risk perception.

To account for some of those disregards and considering existing risk perception assessment methods, findings in risk communication research were consulted. Especially the analysis of MMs has proven useful in determining the difference between laymen's and experts' risk perception (Atman, Bostrom et al. 1994; Morgan, Fischhoff et al. 2002). Experiences with the Mental Model Approach (MMA) leaded furthermore to the expectation that its application for the assessment of rural risks could overcome the found research gaps of the commonly used SLF. However two aspects of the MMA had to be bearded in mind. First in the case of farmers, the different types of risks they are confronted with make it necessary to broaden the system boundaries to allow additionally for the analysis of risk trade-offs (Forsyth 2006). Second when experts and laymen risk perceptions are compared, their differences are related mostly to differences in knowledge and

expertise, whereas, individual contexts, motives, values, or even traditions are not included neither in the analysis nor the interpretation of the results (Bostrom 1997; Murphy and Gardoni 2006).
Therefore to broaden the system boundaries regarding individual contexts, this paper presents the Structured Mental Model Approach (SMMA). The SMMA is an approach to structure the MMA by means of the SLF. As such the SMMA overcomes the presented gaps of SLF and MMA by combining the strengths of the two methods. The paper demonstrated how the SMMA was developed while accomplishing the following goals:

- guide the interviews so that farmers' perception of their livelihood and livelihood risks can be compared to the ones of experts
- account for the specific characteristics of the social capital
- guide the interviews so that farmers' and experts' MM are contextualized in farmers' livelihood and the system boundaries sufficiently enlarged to make livelihood risks trade-offs apparent

4.1.2 Conceptual framework

The main underlying idea of the method is to assess farmers' view of his livelihood focusing on one specific risk aspect (e.g. applying pesticides on the crops, changing to a new crop). The contextualisation of any analyzed rural risk in the livelihood context was achieved by prescribing the MM to be composed of the five capitals (human, natural, financial, physical and social capital) of the SLF. To comply with the aims of the research in the method development, the social capital was treated separately, the other capitals, summarized as individual capitals, were investigated simultaneously and in relation to each other. The combination of MMA and SLF are explained in more detail in the paper 1 and the theoretical background chapter of this thesis.

The approach is adaptable to the assessment of MMs of all kinds of rural risks. Depending on the specific risk the individual livelihood capitals, structuring the interview, can be adapted. For example, for the case of health risk, a health capital should be incorporated in the livelihood structure, or for the case of a specific environmental risks and risk tradeoffs the natural capital should be differentiated, e.g. structured in different environmental spheres (soil, water, air, etc.) or in the case of human capital, different human capital spheres (traditions, private or federal schools, technical support, consultancies) should be used for structuring the livelihood. But overall important is that the livelihood assets remain containing all aspects of farmers' livelihood.

Finally the approach is structured in four parts: one prerequisite part; two parts concentrating on the definition weighting and dynamics of the individual capitals: and one part concentrating on the same aspects for the social capital.

4.1.3 The SMMA

The approach is developed as a one to one interview with an average length of 1-2 hours. For one complete dataset so many interviews have to be conducted that a) for the experts an overview of the experts' knowledge of farmers' livelihood is obtained and b) for the farmers no new MM concepts are obtained during the last three interviews.
The experts are selected to have a field of expertise in one or more of the farmers' livelihood capitals and as many experts as necessary to cover the problem under investigation. Furthermore experts selected for the interview should be important suppliers of information, therefore they should be directly or indirectly linked to the agent network of farmers.
The farmers are selected as being key in the problem under investigation as recommended by Morgan et al. in MMA (Morgan, Fischhoff et al. 2002). Furthermore farmers selected for the interview should differ in livelihood type and therefore cover all different kinds of livelihood types occurring in the investigated area (poor, rich, of high education, small holder etc.).
The SMMA is structured, besides the introductory part, in three main parts: Part I: Definition and weighting of the individual capitals; Part II: Analysis of the livelihood dynamics among the individual

capitals and; Part III: Definition of the social capital represented by the agent network. (the structure of the SMMA can be seen in Table 2 Paper 1)

The goal of part I is first to investigate and detect possible deviations in definition and weighting of farmers' individual capitals. In other words, to measure the difference between experts' and farmers' statements, concerning the definition and the importance given to farmers' individual capitals. For that purpose the individual capitals of farmers' livelihood are defined by the interviewed subjects by either naming characteristic elements of each of the capitals (in the case of experts) or by sorting photographic representations of the characteristic elements in the four individual capital groups (in the case of farmers). In this manner the pure definition of each individual capital and consequently what type of risk it is associated with is investigated. The more an element is named by the farmers to define other capitals then the one assigned by the experts, the more the definitions of experts and farmers deviate.
In addition the interview subjects are asked to rank the four capitals by order of importance for farmers' livelihood. In this way preferences among the capitals are unfolded. The more the importance ranking of the individual capitals differ, the more do farmers and experts priorities and trade-offs concerning farmers' livelihood differ.

The goal of part II is to compare experts' and farmers' influence diagrams of the four individual capitals concerning a specific risk under investigation (e.g. introducing a new agricultural technology, new seeds etc.). In other words, the goal is to measure the difference between experts' and farmers' influence diagrams, and thereby to measure the difference in risk perception and weighting of trade-offs.
The experts' model obtained first is used for designing farmers' interviews, such that differences between experts and farmers will point priorities and trade-offs among the investigated individual capitals. For that purpose the experts are asked to draw an influence diagram of the four individual capitals and the farmers are asked ten open-ended questions about the dynamics and relations within the influence diagram. Finally the experts' diagrams and farmers' answers are summarized in capital state and capital effect statements and compared. The more the statements concerning capital state and capital effect within the influence diagram deviate, the more do farmers and experts perspectives deviate.

The goal of part III is to identify and measure the difference in perception between farmers and experts concerning the social capital of farmers.
This is achieved by letting experts and farmers construct a farmers' agent network by placing photographic representations of the agents into a network form. Subsequently the networks are compared by definition and placement (distance to farmer and structure of network) of the agents in farmers' agent network.
The more the definition and the placing of the agents deviate the more do the perspectives of farmers and experts concerning the social capital deviate, the more will the conclusions drawn from the agent network and the decisions made based on the agent network deviate.

4.1.4 Discussion

This first publication shows that the SMMA enables to pinpoint specific differences between experts' and farmers' views concerning the definition, prioritization and dynamics among the livelihood capitals.
Concerning the first research aim of the paper, the developed method includes the local knowledge and the individual context of the interviewed subjects by analyzing and comparing livelihood capital definition, weighting and trade-offs among subjects with different local knowledge and different livelihood context. It was taken into practice that differences in capital trade-offs between experts and farmers can be attributed to different sources, namely capital definition and relative weighting of capitals. This means depending on local knowledge livelihood capitals are defined differently and/or weighted differently and therefore trade-offs between capitals are perceived differently.

Such that decisions made concluded from the MM of the livelihood are different. By applying the SMMA the definition and the weighting differences of farmers and experts can be made explicit.
Concerning the second research aim of the paper, the developed method handles the social capital separately and accounts thereby for the specific role of social capital in the livelihood context. Social capital consists of agents and the agents can be trusted or frequented such that the definition, weighting and trade-off within social capital depends on the same aspects but concerning the agent involved in the social capital. The SMMA takes this particularity into account by analyzing the social capital by means of perceived agent networks of the interview subjects. Obtained results, from the first application of SMMA, suggest that the analysis of farmers' agent networks gives significant insights on the role and influence of different agents such that key agents can be selected and cooperated with.
Concerning the last research aim, the inclusion of all risks farmers' trade within their livelihood, made the analysis of decision-making with respect to a specific risk possible. The SMMA reveals the effect of a specific risk (such as pesticide application health risks) in the context of different livelihood capitals by unfolding the relative weight of a risk. This gives a more holistic view on the actual decisions made to be related to a specific risk, and even takes indirect risks considered by the farmer into account.
Regarding the policy relevance of the method, it is considered that the results that can be obtained with the SMMA provide a sound basis for the design of communication and educational programs. Risk communication is more effective if it is related to the whole system influencing the subjects' lives. In addition, experts' understanding of the embedding of pesticide risks in farmers' livelihood allows them to develop strategies and options for change that consider farmers' priorities and viewpoints. Given their understanding of farmers' thinking, it is predicted that it should be possible to develop strategies in expert-farmer teams.

4.2 Paper 2

System Perspectives of Experts and Farmers Regarding the Role of Livelihood Assets in Risk Perception: Results from the Structured Mental Model Approach
Journal: *Risk Analysis (Vol. 29, No. 2, 2009, pp. 205-222)*
Authors: Schoell, R. and Binder, C.R.

4.2.1 Motivation and research goals

With increasing need for food and effective production of agricultural products, misuse of pesticides is a problem especially in developing countries. Misuse of pesticides in developing countries relates to (i) lack of adequate protection during the mixture and application procedure; (ii) inadequate storage facilities (iii) a higher amount and frequency of application than in industrialized countries and (iv) the application of stronger products often forbidden in industrialized countries (Chandrasekara and Wettasinghe 1985; WRI 1998; Wilson and Tisdell 2001).
In spite of major efforts by the international community to develop information programs and investments of pharmaceutical companies to foster educational programs, farmers continue to misuse pesticides.

One of the reasons is that to a large extent, farmers' perception of risks related to pesticide use, has neither been investigated, nor included in the development of educational programs. Studies have mostly focused on understanding what variables might influence pesticide application behaviour, but pesticide reasoning behind pesticide behaviour has not been investigated so far.
Additionally, pesticide misuse has never been put in relation to other types of risks affecting farmers' livelihood. Thus, we consider that farmers' risk perception should be investigated and farmers' perception of pesticide risk compared to the perception of the other risks they confront. Perception is thereby defined as process of acquiring, interpreting, selecting, and organizing information (Bostrom, Fischhoff et al. 1992)

Derived from the presented pesticide misuse problem the SMMA appeared to be the appropriated tool to analyze causes for pesticide misuse of farmers. This paper therefore demonstrates how the SMMA was first applied empirically. It describes how the SMMA was adapted to analyze the perception of pesticide risks and what the perceptions and differences in perception of farmers and experts were, concerning pesticide risks.
The SMMA was applied to find possible existing communication failures expected to cause the observed inappropriate pesticide use. Therefore the MMs concerning pesticide use in the context of farmers' livelihood of farmers and experts were derived and analyzed.

This paper presents the application of the SMMA for the case of pesticide management in potato growing. Thereby the SMMA was applied to farmers in Vereda la Hoya, Boyaca, Colombia. The following research goals were investigated:

- analyzing farmers' and experts' discrepant MMs of their risk perception of pesticide management within the livelihood context of farmers
- exploring the causes of discrepancies between MMs of experts and farmers
- analyzing inappropriate pesticide management with respect to risk communication

4.2.2 Method

In this first application of the SMMA the method was adapted to the specific context of pesticide misuse, this implied to adapt the livelihood assets to a more health risk related problem. Therefore the new redefined capitals were human, natural, financial and health capital. See Figure 15 as an illustration for the individual capital adjustments of the SMMA.

Furthermore the SMMA was adapted by adjustments to the three parts of the interview, as well as adaption of the prerequisite phase, introducing the interview as an investigation of pesticide use in the study region.

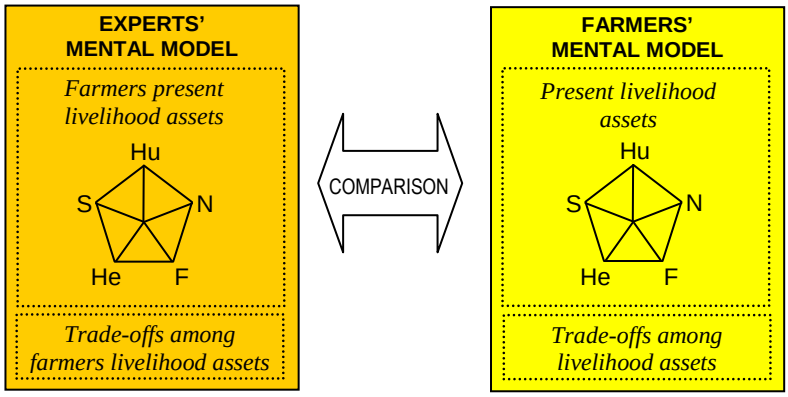

Figure 15: Adaptation of the Structured Mental Model Approach for pesticide use. With adapted livelihood assets: Hu=Human Capital, N=Natural Capital, F=Financial Capital, He=Health Capital, S=Social Capital

The farmers as well as the experts were chosen to optimally cover the pesticide application problem. That implies that the chosen experts were concerned about pesticide misuse and were linked directly or indirectly to the chosen farmers and the farmers' livelihood (see Table I Paper 2). The experts were actively involved in campaigns together with the farmers or were members of an institution involved with farmers' rural professional training or rural development programs. The farmers chosen were from a region known for inappropriate pesticide use, e.g. farmers had been observed to carrying insufficient pesticide protection equipment (PPE) while handling pesticides or suchlike. Moreover farmers where chosen to represent all livelihood structures appearing in the study region (Table II Paper 2).

Part I of the SMMA was adapted to the pesticide risk perception problem by introducing the health capital to be one of the four individual capitals defining all livelihood assets a farmer has at hand. Experts, asked to name important characteristic elements of the four individual livelihood capitals,

included and assigned pesticide specific elements in the definition of the individual livelihood capitals (e.g. pesticide mixing, pesticide spraying or just purchase pesticides in the local store). In the second step experts were asked to rank the livelihood capitals in order of importance to farmers' livelihood. Derived from the capital defining element given by the experts, the photographic representations were taken and used for the farmers' interview. Farmers were not specifically reminded of the pesticide context during this part of the interview. That is although having pesticide specific elements to recognize, to arrange and to weight, the overall prioritization of all individual livelihood capitals was warranted.

The adaptation of part II of the SMMA mainly consisted in focusing experts' system dynamic explanations on pesticide application concerns. Consequentially farmers ten open ended questions were tailored first to compare the found system perspective of the experts with the perceptions and views of farmers and second to guide farmers' conversation around the topic of pesticide use (e.g. were the fathers using also pesticides?) For more examples of the specific questions consult the corresponding paper.
Also the social capital analysis, part III of SMMA, was operated in viewpoint of pesticide use. Therefore the question to construct the agent network of farmers by experts was guided by the request to include agents in the network needed for pesticide management issues. Consequently the agent photographed for the farmers' agent network questions included agents like a pesticide seller. However the guiding question for constructing the network was focused on farmers' livelihood in general. Therefore the agent network does not provide a direct insight about information concerning pesticide management per se.
Finally farmers' and experts' answers of each part of the interview were compared and deviations analyzed. Originating from the MMA, agreement among the expert statements should be reached, yielding one comprehensive statement, and the farmers' diverging statements then compared to that single expert MM. The results of the SMMA were analyzed and structured according to the three steps of the method. Based on the SMMA the analysis of the interview is independent of the pesticide focus.
A more detailed description of the Future-SMMA method and the interviewed subjects can be found in the method section of the corresponding article.

4.2.3 Results

Results found in the study and presented in the paper demonstrate a clear divergence between experts and farmers MMs. Experts and farmers differed in all three aspects of the analysis obtained from the SMMA application. They differed in the way they defined the livelihood capitals, differed in the weighting by importance of the capitals and had different views concerning the dynamics of the system consisting of all four livelihood capitals.

Results found in part I of the interview showed that farmers and experts differed in the way they defined and weighted the livelihood capitals, implying by that, that when experts talked about a specific livelihood capital in order to transmit information, farmers were thinking about a different livelihood capital and concluded different measures than the one intended by the experts.
One of the clearest examples found in this respect was that, the element religion was used by the experts to define human capital whereas farmers used it to define health capital. Moreover farmers weighted health capital as most important and human capital as least important and experts weighted these two capitals inversely.
These deviations were found to be the source of farmers and experts misunderstandings and they offer an explanation for farmers' behaviour. That is instead of wearing pesticide protection equipment (PPE), farmers try to stay healthy by praying. Religion as being part of the health capital by the definition of farmers is used to follow the demand of experts to improve health capital instead of using PPE. Therefore religion should be considered when experts try to improve wearing PPE, e.g. by explicitly explaining that PPE is a necessary additional measure not replaceable by prayers.

Results found in part II of the interview were that farmers and experts had different explanations and reasoning concerning the interaction of system elements of the livelihood system of farmers.

These findings provide an explanation about why and how certain information, provided by the experts to farmers, in order to meliorate the system, was interpreted differently by farmers.
For example an improvement in financial capital was assumed by experts to lead farmers to invest more money in sound techniques for potato cultivation. In contrast to that farmers stated that they would not invest more in potato production as they fear overproduction and consequently the risk of declining potato prices. Farmers would prefer to invest in alternative means of income e.g. to grow other crops or invest in animal husbandry.

Also the results found in part III demonstrated clearly a deviation of experts and farmers perspectives. For example while experts were convinced that the pesticide sellers were important for the farmers in their agent network, farmers expressed their distrust towards pesticide sellers by placing in their network agricultural technicians for animal husbandry or crop production, the church and even pesticide producing companies closer to themselves then pesticide sellers.
Overall crucial differences between farmers' and experts' MMs were identified, explaining to some extent the lack of success of educational and intervention programs. The differences were made explicit in the SMMA at the level of definition of the individual capitals, ranking of the capitals, system dynamics and agent networks.

4.2.4 Discussion

The discussion of the paper was structured in three parts. The first part consists of the derivation of causes for the discovered differences in farmers' and experts' perspectives, and relates to them the inference of measures to meliorate pesticide use concluded from the discovered differences and their possible causes. The second part consists of presenting some strengths and limitations, drawn from the first application of SMMA. The third part consists of suggestions for further research.

Explanations for deviating MMs and improvement of risk communication
The three main explanations for the discrepancies between the MMs and risk perceptions of farmers and experts discussed in the paper were: (i) the role of tradition; (ii) trust in the source of information; and (iii) feedback on knowledge adjustment.
All three were discovered to additionally influence the construction of farmers' MMs and risk perception such that they turned out to be the key elements of concern in order to improve educational programs and suchlike.
The central role of tradition to explain discrepancies of farmer and experts MMs is documented by the role of religion concerning health protection issues and traditional production measures. This finding is in line with the socio-cultural perspective, which states that culture and culture (traditions, religion, and worldviews) might indeed significantly influence the risk perception of agents (Slimak and Dietz 2006; Taylor-Gooby and Zinn 2006). Nevertheless the obtained results of the study exemplify the role of additional sources of information for the farmers compared to the ones experts believe farmers' have, and that these additional sources were not sufficiently considered in educational programs so far. By the clarification of the kind of additional information, via the application of the SMMA, optimised communication measures can be drawn.
The role of trust in the source of information indirectly influencing the building of farmers' MMs was best demonstrated by the exercise to construct an agent network during the SMMA. Thereby farmers explained/commented their placements in the agent network mostly by traits of trust, e.g. farmers placed pesticide producers closer to themselves than governmental technical assistance, commenting that they had more trust in pesticide producers. Three possible traits of trust could be identified (i) contact intensity, (ii) experiences gained concerning the quality of the information given, and (iii) willingness to use information from certain sources. All three were exemplified in more detail and related to earlier findings of a similar kind in the discussion section of the paper. They demonstrate the importance of frequent visits and reliability of the information provided to farmers, in order to establish a persistent and effective communication among farmers and experts.
Feedback on knowledge was found to be another important cause explaining deviations of MMs. The results suggested that e.g. farmers definitions of products were the result of mainly three

feedback mechanisms: (i) intuitive toxicology (i.e. bad smell classification), (ii) experimental knowledge (i.e. experienced effectiveness of a product), gained by applying the product, and (iii) the information formally obtained from the introducer or promoter of a product. This threefold feedback characterisation is critical in the understanding of farmers' protective behaviour. For example the experimental knowledge implies that information to which no experience can be related does evoke an interruption of the feedback mechanism. Thus information on protection measures (wearing PPE), where people are taught to change a habit to avoid a certain not experienced negative effect are unlikely to be incorporated in the MMs. Hence most of the found farmers' pesticide protection measures were self-constructed confirming farmers own beliefs (confirmed by findings of Severtson and Slovic) and give a new example of the difficulty that experimental thinking faces in dealing with outcomes that change very slowly over time. Having these findings in mind experts should refrain to give long-term recommendations neglecting farmers' insensitivity towards such kind of information and concentrate on short-term recommendations.

Strengths and Limitations
As a main strength of the SMMA the provision of a structured analysis to understand the relevance of different risks in relation to farmers' livelihood was affirmed in this first SMMA application. The most critical limitation of the method was found to be the differing opinions of experts and especially experts of different fields of competence were difficult to compare.

Further research
Emerging from the confronted strengths and limitations of the SMMA, the validation of the results in an extensive survey and a closer look to agent networks were seen to be further research tasks (immerging from the first SMMA application). Furthermore the study and its results opened the possibility of developing a measure for the degree by which the experts of different fields differed regarding their MMs. Moreover the development of a culture specific typology of farmers comparing examples of small holders in Latin America, Asia and Africa was stated as a possible further challenge. Such a typology was seen to allow specifying intervention programs according to similarities and differences among the compared culture.

4.3 Paper 3

Comparing system visions of farmers and experts
Journal: *Futures (Vol. 41, No. 9, 2009, pp. 631-649)*
Authors: Schoell, R. and Binder, C.

4.3.1 Motivation and research goals

The future of agricultural production is closely related to the future of environmental conditions and to the future of farmers producing agricultural products. Ongoing misuses of pesticides continue to deplete soils and destroy biodiversity even more, in the future (Lewis and Newbold 1997; Wilson and Tisdell 2001; De Jong and De Soon 2002; Kovach and Petzoldt 2004; Van den Brink and Crum 2004). On the one hand, farmers are presumably unaware of this effect, which could explain why they continue to misuse pesticides in spite of a possible destruction of their subsistence basis (Rahman 2003; Swinton and Escobar 2003). On the other hand, farmers are suspected not to care about the negative effect of pesticides.
That farmers are unaware of these effects can be attributed to communication failures between experts and farmers (as in Paper 2). Farmers' apparent indifference towards the negative effects of pesticides can be explained by trade-offs between different desires for the future. In other words, just as inappropriate pesticide use is attributed to different MMs and livelihood perspectives (in

Paper 2) it also could be attributed to deviating future scenarios[4], different future livelihood perspectives and different desires for the future.
In order to analyze if deviating future visions influence inappropriate pesticide use, farmers' (inappropriately applying pesticides) and experts' (giving advice concerning pesticide handling) future visions are derived, compared and analyzed in viewpoint of their differences which to the knowledge of the author has not been done so far.

Moreover, the future of farmers is determined by external factors (e.g. changing climate or agricultural markets) and internal factors (e.g. livelihood assets, self-perception, behavior).
External factors cannot be controlled by the farmers. They constitute external constraints to farmers' future and are best known by local experts (Ellis 2000; de Haan and Zoomers 2005). External factors and how they may be handled can be communicated to farmers, but misunderstandings can occur, caused either by deviating MMs (Morgan, Fischhoff et al. 2002) or by neglect of livelihood context [research gap article 2].
Internal factors are determined by the farmers and their importance for agricultural development has been stressed by several research groups (Ellis 2000). Internal factors determine farmers' MMs (especially farmers' future scenarios) and how farmers view their livelihood context as well as their desires for the future (future visions). Furthermore, concerning farmers' development, positive changes are more likely to be initiated when the attitudes, beliefs or preferences of the people managing or depending on resources are considered according to the identification of problems and the development of solutions.
But external and internal factors have not been considered simultaneously yet, neither in future research nor in risk-communication research. Neither for investigating future visions of farmers nor for understanding better the relationship of future visions in relation to risky present behavior

Therefore, the aim of this paper is to identify and compare farmers' and experts' future. Exemplarily this is done in terms of the pesticide management of potato growing farmers in Vereda la Hoya (Boyacá, Colombia) [the same study area as for the application of the SMMA, Paper 2]. Moreover by analyzing deviations in farmers' and experts' future visions, we inferred new explanations for causes of pesticides misuse.

To accomplish the aim of this paper the following research goals have been tackled:

- investigate farmers' future visions in the context of their livelihoods
- compare farmers' and experts' future visions and perceptions of external constraints on farmers' future
- determine how farmers' livelihood assets and self-perception influence the building up of farmers' future visions

4.3.2 Method

To find communication failures which are expected to cause inappropriate pesticide use, farmers' and experts' MMs of the future (future visions) were compared. As for the SMMA, the comparison of experts and laymen in a rural environment delivered good results, it was decided to use the same method and adapt it to the future context. As a first step, the research goals were identified and described by means of the SMMA theoretical framework. Subsequently, on this basis the SMMA was redesigned in viewpoint of the future (see Figure 16 for the adaptation of Future-SMMA for pesticide use). The newly adapted SMMA was named Future-SMMA and designed, in viewpoint of the research questions, to analyze: a) Biases to future visions caused by the livelihood context of farmers; b) Future vision differences of farmers and experts; and c) Biases to future visions caused by different desires for the future.

[4] Future scenarios = mental models of the future; Future visions= future scenarios + desires

For the study, 13 experts and 10 local farmers were selected by purposeful sampling and interviewed with the Future–SMMA. Most of the participants had participated before in either in the SMMA or the system analysis workshop conducted in the study region or both.

In order to focus on the future perspective, the Future-SMMA differs from the SMMA in two main aspects. The farmers, as leaders and determining their internal factors of development, are interviewed first, building the basis for the experts' interviews. Apart from that, the open-ended questions concerning the system-dynamic perspectives were reformulated in viewpoint of the future described in the first part of the interview.

Therefore, the Future-SMMA consists like the SMMA, of a prerequisite phase and three analytical parts: 1) definition and ranking of possible futures; 2) potential effects of these futures on farmers' livelihoods; and 3) future agent network (see Table 1, Paper 3).

Each of the interview parts pursues a specific goal and was therefore adapted by the SMMA to reach that goal. The goal of part I is firstly to obtain an idea of farmers' general view of the future; and to prioritize four futures that farmers envision. Secondly, it aims to compare the envisaged ideas with experts' opinions about desirability and feasibility of farmers' envisioned futures. Therefore farmers were asked to construct a desired future and subsequently to rank four previously constructed futures in order of preference. Likewise, experts were asked to discuss farmers' desired futures and to rank the same four futures farmers had ranked by order of feasibility.

The goal of part II is first to understand how farmers perceive the consequences of their visions for the future on their current situation from a system development perspective. Second, it aims at obtaining local experts' views on the constraints farmers might face in reaching their preferred future. For that purpose, farmers were asked 10 open-ended questions about the relations of the elements of the capital groups with respect to their preferred future selected in part I. In comparison to that, experts were asked to elucidate how the system elements (see Table 2, Paper 3) would develop by the year 2017, by naming three expected levels of development for each element. The levels were: 1) best case, 2) intermediate case and 3) worst case.

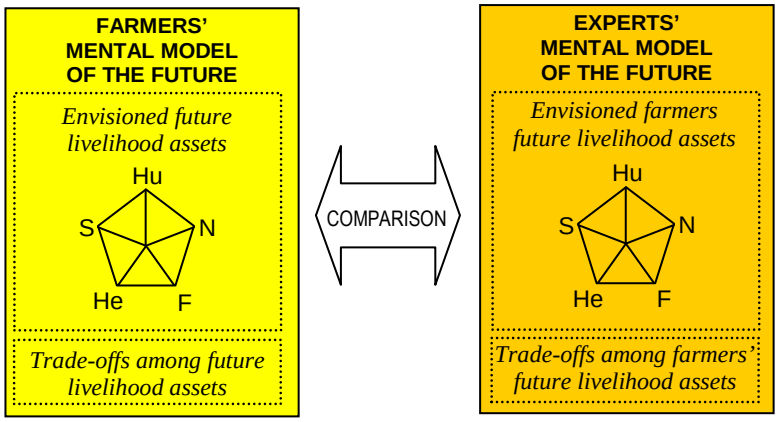

Figure 16: Adaptation of Future Structured Mental Model Approach for pesticide use. With adapted livelihood assets: Hu=Human Capital, N=Natural Capital, F=Financial Capital, He=Health Capital, S=Social Capital.

The goal of part III is to compare farmers' and experts' agent networks so that misunderstandings of agent roles can be identified and tackled in order to optimize policy recommendations for the achievement of farmers envisioned futures.
Therefore, farmers and experts were asked to construct an agent network that reflects the relative importance of agents necessary to achieve farmers' envisioned future.
In each of the interview parts answers from the farmers' interviews were analyzed and summarized and used as a basis for the experts' interviews. The results of the Future-SMMA were analyzed and structured according to the three steps of the method. Finally, farmers' and experts' answers of each part of the interview where compared and deviations analyzed. Originating from the MMA, agreement among the expert statements should be reached, yielding one comprehensive statement, and the farmers' diverging statements then compared to that single expert MM.

A more detailed description of the Future-SMMA method and the subjects interviewed can be found in the method section of the corresponding article.

4.3.3 Results

Similar to the SMMA, applied in the same study area, differences between farmers' and experts' expectations for the future were found throughout all three parts of the interview.
Results found in part I of the interview showed that, besides, seeing different consequences and prerequisites to achieve a certain future, farmers and experts differed considerably in the ranking of feasibility and desirability of four futures. They ranked inversely the futures *Cooperative* and *Technical schooling*, farmers ranking *Technical schoolings* first and *Cooperative* second in contrast to the experts' ranking. The same inverse ranking was observed for the futures *Status quo* and *Integrated Pest Management (IPM)* where farmers ranked *IPM* in third and *Status quo* in fourth position inversely to experts' ranking.
Results of part II indicate that system dynamic perceptions and opinions differed substantially. Farmers' visions were optimistic. They were convinced that all capitals, except for the financial capital, would improve in the near future. Furthermore, it was found that farmers do consider social and environmental threats. Conversely, experts were more pessimistic concerning the actual development of the capitals and predicted a deterioration of all capitals but the human capital. In addition, experts are worried that farmers do not sufficiently consider external constraints.
Finally, the agent networks of farmers and experts, emerging from part III of the interview, differed by the position of the agents, according to its importance to achieve an envisioned future. For example, the experts placed the agent "union" to be one of the most important ones, whereas for the farmers, the union was not going to be the starting point of founding a cooperative.

In viewpoint of the research goals, farmers' visions were found to be threefold; they either envision to create a farmers' cooperative or to improve/coordinate better the technical schooling they receive or to adopt integrated pest management ideas. None of the farmers imagined that the status quo could be maintained. The investigated future visions of farmers and experts were inconsistent considering future definition, ranking of futures and importance of different agents involved to achieve the future. Finally, by analyzing farmers' answers in viewpoint of their different livelihood background it was found that the more a farmer was able to differentiate his livelihood assets, the more differentiated were his future visions.

4.3.4 Discussion

By adapting the SMMA to the future context, with reference to the research goals, it was possible to investigate farmers' future visions in the context of their livelihood and to find key relations between farmers' future visions and their present behaviour concerning pesticide use. Judging by the findings, the developed Future-SMMA is a suitable tool to compare farmers' and experts' visions in order to grasp solutions for a sustainable agricultural development inherent in the system. Finally, by the purposeful sampling of the interview subjects, first insights about a relation of livelihood context and kind of envisioned future could be drawn.
Furthermore, it was found how the revealed inconsistencies of future visions of experts and farmers are caused by diverging attitudes towards future scenarios and different opinions about who should take the responsibility for the knowledge management of farmers. These two aspects have to be considered in the successful design of agricultural development plans.
Diverging attitudes of farmers and experts towards the future were found to lead to an unwillingness of experts to listen to farmers' demands (e.g. IPM not being introduced in the study area) and hinders a constructive development process. This results are comparable to other findings such as the ones of Wheeler (Wheeler 2008).
Different opinions about who should take responsibility for the knowledge management of farmers opens up a vacuum, e.g. of knowledge provision, which biased entities such as pesticide selling companies currently seem the most willing to fill. This discovered process possibly leads to an increasing dependency of small holders upon pesticide suppliers. Furthermore, the latter gives rise

to the question if a higher dependency of smallholders is in line with a sustainable agricultural development or not.

Adapting the SMMA to the future revealed one limitation. Investigating the future opens up a much broader view of the system than investigating the present, implying all strengths and limitations of broadening system views. On the one hand, new perspectives could be gained on relations among elements not traced by narrow system boundaries. On the other hand, the focus and precision of the analysis are diluted. The future focus definitively forces one to increase the number of participants especially for the number of interviewed farmers. Therefore, the small number of interviews conducted constitutes a shortcoming in the validity of the Future-SMMA. It is recommended to validate the results by a survey, as suggested by Morgan (Morgan, Fischhoff et al. 2002).
In addition, to confirm the influence of livelihood assets on future visions, the analysis of the cause-and-effect thinking of farmers, as suggested by Mackay and McKierman (2004), would be important and could be performed by comparing results of the Future-SMMA with the ones of the SMMA.

4.4 Paper 4

Comparison of farmers' mental models of the present and the future: A case study of pesticide use
Journal: *Futures (in press, 2010; doi:10.1016/j.futures.2010.04.030)*
Authors: Schoell, R. and Binder C.R.

4.4.1 Motivation and research goals

Analyzing the influence of past and present on future images Blackman and Henderson (2004) argue that foresight can be defined as being MMs about the future. She states: "foresight is merely a picture, a MM to guide decisions and actions operating between the present and the expected future state. The efficiency of the foresight depends upon both the accuracy of the MM and the consistency of the actions with it." The aim of this paper is to investigate the accuracy of the future MMs of pesticide application.
Present MMs of the Vereda la Hoya farmers (Paper 2) were compared to Future MMs (Paper 3). This allows to investigate the dependence of the latter on the former. The comparative study reveals new insight on causes for inappropriate pesticide applications and reasoning behind the reluctance to use protective equipment during pesticides application.
Concerning the comparison of present and future MMs, the conducted literature review showed that only a few studies have actually compared MMs of the present with MMs of the future, none of them in the field of Future Studies. Nevertheless comparing present and future causal relations may show misapprehensions in MMs or lead to enhance the understanding of epistemological peculiarities of future MMs. Hence the comparison of present and future MMs represents a missing task of Future Studies.
Concerning the dependence of future on present MMs we conclude in the paper, that research findings exist in favour of a clear theory of dependency of future on present MMs but that actual dependency characteristics have not been demonstrated so far. Moreover, the comparison of present and future MMs of people concerning a specific technical example like pesticide effects in the present and the future, could constitute a new approach in Future Studies to investigate how future MMs are determined by present MMs.

Therefore the paper pursued four goals which can be summarized as the following:

- compare MMs of the present and the future systematically
- determine the dependence of future MMs on present MMs
- derive, for the case study of pesticide application, how farmers' present and future MMs differ with respect to different livelihood capitals
- investigate if present and future MMs of farmers' pesticide application differ among farmers

4.4.2 Method

Using the conceptual framework of the SMMA and the Future-SMMA the aim of this research is illustrated in the Figure 17.

In order to compare present and future MMs both have to be collected from the same subjects and concern the same specific topic suitable for explanation and prediction theory. An appropriate dataset has been gathered from potato producing farmers making decisions about, if and how to use pesticides for agricultural production now and in the near future. The data were collected applying the SMMA (Paper 2) and the Future-SMMA (Paper 3). Going through the three analytical parts of the approach the results obtained from part I and III of both approaches respectively, deviated too much to be compared. In contrast to that the comparison of the results for part II were suitable for the aim of the study.
Reasoning about matters of fact (such as in Part II of the SMMA and Future-SMMA) is, as Hume says, largely based on causal relations (Johnson-Laird and Byrne 1991). According to Goldvarg and Johnson-Laird causal relation allows to infer what will happen (Goldvarg and Johnson-Laird 2001) such that investigating causal relations in MMs may reveal what is inferred by MMs. Thus to analyze and compare the statements of part II of the SMMA interviews, the statements were organized in causes and effects. The classified causes and effects of the SMMA were directly compared to the Future-SMMA causes and effects and assigned to one of six different cases of comparability. The cases differ depending on whether the causes and the effects of each pair of statements coincided or not. Each of the cases related to a different dependency of present and future statements and can therefore supply additional information and reasoning to understand decision-making (Chermack 2004). Important to note is that, explanations and predictions were seen as identical only if case and effect of a statement coincided in the present and the future MM.

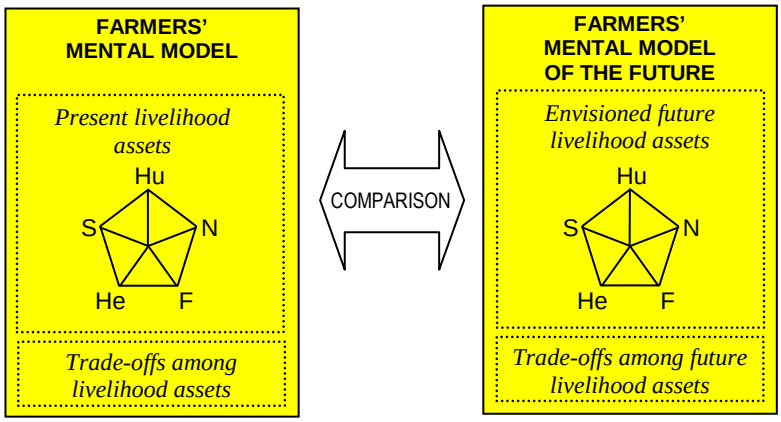

Figure 17: Comparing data from SMMA and Future-SMMA. With adapted livelihood assets: Hu=Human Capital, N=Natural Capital, F=Financial Capital, He=Health Capital, S=Social Capital

The classification of a pair of statements into a comparability case was associated thereafter with the level of dependency by case or effect or both or neither nor. Furthermore the classification revealed with the characteristic of the investigated capital or farmer to which degree the farmer was able to relate present to future and to which degree it differed with investigated capital.
The results for part II were summarized in two ways. First all the capital statements of farmers for the present and the future were summarized and compared on an aggregate level to each other as a whole, second each present and future capital statements of each farmer were compared individually.
For further details on the method see the corresponding section in the Paper 4.

4.4.3 Results

The comparison of the SMMA and the Future-SMMA revealed the following research results.
By applying the comparative method and using the obtained data from the two previous studies it was possible to compare present and future MMs and analyze differences of explanation and perception of all livelihood capitals. The found differences for the individual capitals indicated dependencies of present and future MMs by cause, effect or both. The deviations differed by analyzed capital and by interviewed farmer. Concerning the found differences of the capitals, the natural capital was found to have with 70% the highest occurrence of cases where cause and effect of the present and future statements were identical (case 1). In contrast to that the lowest occurrences of case 1 statements was found for the health capital. Concerning the comparison of individual farmers, three types of farmers were found: 1) the deductive effect focused farmer 2) the deductive cause focused farmer, and 3) the imaginative effect focused farmer.

4.4.4 Discussion

This paper constitutes the first attempt to compare present explanations and future prediction, in order to elicit the dependence of future from present MMs.
Differences and dependencies throughout the different capitals found by comparison of present and future MMs on an aggregate level, justified the importance to consider all livelihood capitals simultaneously. This finding underlines that considering differences in logic of different capitals helps to characterize further farmers' dependency of future on present MMs more appropriately.
The accuracy of the foresight MM can only be measured by the comparison to the actual decision-making. The found difference between present and future individual capital dynamics seems to be correlated with some observed decision-making failures. For example the findings are in line with the observed shortcomings in use of protective equipment which represents a failure in relation to health capital. In addition, the findings are consistent with the observed more reasonable treatment of natural capital.
The different occurrences of cases among the different capitals, on an individual level of analysis, were classified in three kinds of farmers' statement patterns. Some farmers (*the deductive effect focused farmer*) where found to expect different cause to lead to the same effect in the present and the future[5]. In contrast to that other farmers (*the deductive cause focused farmer*) focused on the causes and allocated to the same causes in present and future MMs different effects in the future and in the present[6].

Several strengths and limitations' of the comparative method were derived.
First the method constitutes a way to prove that explanation and prediction differ and how they differ. Thereby the method underlines the importance of future studies as the found results proves that it is not sufficient to only and exclusively consider present MMs in order to understand perception of risks consistent with findings of Morgan(2002) and Aligica (2003).
Second strength of the method is that it contributes a measure for problem recognition as seen by the research findings of Engel, Kollat and Blackwell (1968).
Third, according to Harries argument, the revealed inconsistencies of present and future MMs showed mechanisms of learning processes of individuals and the role of future MMs for those learning processes. Hence the method constitutes a way to learn in which way MMs of subjects should or could be altered. According to Herries (2003) and Chermack (2006) scenario planning has a utility in extracting, developing examining and refining individual theories-in-use. Hence rules

[5] Example of "*the deductive effect focused farmer*": cause in the present: over dosage of pesticides; cause in the future: pesticides are expected to be more toxic; effect in the present and the future: degradation of the soils.

[6] Example of "*the deductive cause focused farmer*": cause in the present and future: improper protection while applying pesticides; effect in the present: health damages; effect in the future: less need of protective equipment;

of thumb and therefore decision making based on rules of thumb (Goldvarg and Johnson-Laird 2001) could be improved by deducing policy measures from the obtained results of the study.
However to confront the three main limitations of the study, namely “openness of the questions”, “time gap between SMMA and Future-SMMA” and “sample size” we added to the paper some suggestions to improve the method. First we propose to add some closed questions to the interview in order to additionally test the logic assumptions of the interview subject. Second we recommend that the interview should be carried out during the same interview session. Third even though the SMMA and Future-SMMA findings demonstrated to be sufficiently stable after 4-5 interviews, the comparison of the two showed a variety of possible thinking patterns. It would therefore be important to interview more farmers in order to weight the occurrence of different statement patterns.

The method presented in this publication may serve a as a basis to do a more elaborated catalogue of questions or investigation to elicit the relation of present and future causal realtions in order to learn more about the basis of decision that people draw from their MMs together with their aspirations to actually reach a desired future.
Among the most promising suggestions for further research in the publication, in this summary we want to mention the following two.
First it would be interesting to compare the found results with results of farmers which had a special pesticide use training, in order to test if the trainings had an influence on farmers’ future MMs. Second the method could be enlarged to compare uncertainty issues between present and future MMs. Such as how certain is the present and the future for interview subjects and what a role plays uncertainty in using comparative arguments in present and future MMs.

5 Concluding remarks

To understand the reasoning behind the use of pesticides in the present and future, the SMMA was developed, combining for the first time the Mental Models Approach (MMA) with the Sustainable Livelihood Framework (SLF). The approach was developed to assess the MMs of a specific problem (e.g. pesticide application) embedded in the broader context of farmers' livelihood.

The method was first adapted and applied to assess the present MMs of farmers and experts, subsequently to assess the future MMs of farmers and experts and, finally the results of the present and future MMs were compared.

Thus this dissertation has managed to give new perspectives to the research fields of MMs, development of livelihoods and future studies. In addition, for the first time the MM concept was framed in the broader context of livelihood perception and related to the tool of scenario planning.

In the following an overview of the main contributions of the thesis is provided. Some suggestions for further research are shown and recommendations and relevance for praxis are also discussed.

5.1 Main overall research findings of the thesis

Experiences from field work in Colombia showed that farmers misuse pesticides, putting up with the risk of health problems and degradation of their environment. From collaboration with pesticide selling companies and by contacting local development agents it was furthermore discovered that education programs concerning the appropriate use of pesticides seem to have failed. Hence the main aim of the thesis was to understand the reasoning behind the use of pesticides in the present and in the future.

The thesis tackled this aim by making two main assumptions. First, if we know what farmers reason and desire, we will be able to better understand why they continue to misuse pesticides; and second, farmers' reasoning and desires concerning a specific problem such as pesticide use are influenced by their reasoning and desires for their livelihood. To understand farmers' reasoning, the important information for farmers' livelihood system is derived via experts' MMs, knowledge and expertise about farmers' livelihood system. Therefore the PhD thesis was structured, as presented in the introduction, in terms of the following goals:

- Develop an approach to compare farmers' and experts' MMs of farmers' livelihood.
- Compare farmers' and experts' MMs of farmers' livelihood with a special focus on pesticide application.
- Compare farmers' and experts' MMs of farmers' future livelihood with a special focus on pesticide application.
- Develop an approach to compare farmers' present and future MMs of farmers' livelihood.

The research goals were considered separately and were further refined in each of the research publications as presented in the summary of each of the publications. The results derived and presented in the different publications of this thesis are summarized in the following Figure 18.

Part one

Findings presented in paper 1

- The SMMA includes the local knowledge and the individual context of the subjects interviewed by analyzing and comparing livelihood capital definition, weighting and trade-offs among subjects with different local knowledge and different livelihood contexts.
- The SMMA handles the social capital separately and thereby accounts for the specific role of social capital in the livelihood context.
- The inclusion of all risks that farmers' trade off within their livelihood made the analysis of decision-making with respect to a specific risk possible.

Part two

Findings presented in paper 2

- Experts and farmers differed
  - in the way they defined their livelihood capitals.
  - in the weighting by importance of the capitals.
  - in their views concerning the dynamics of the system.
- Three main explanations for the discrepancies between the mental models and risk perceptions of farmers and experts found were:
  - the role of tradition;
  - trust in the source of information;
  - feedback on knowledge adjustment;

Part three

Findings presented in paper 3

- Differences between farmers' and experts' expectations for the future were found throughout all three parts of the interview.
- Farmers and experts differed considerably in the ranking of feasibility and desirability of four predefined futures and on the position of agents in the agent network.
- Farmers' visions were optimistic: they were convinced that all capitals, except for the financial capital, would improve in the near future. Furthermore, it was found that farmers do consider social and environmental threats.

Part four

Findings presented in paper 4

- The classification scheme developed to compare causal relations of present and future mental models was based on causal relations differing in cause, effect or both.
- Discrepancies were found for the capitals analyzed and the farmers interviewed.
- Dependencies of future on present mental models revealed misapprehensions and additional factors for prediction.

Figure 18: Overview of research findings summarized for each publication.

The overarching conclusions not referred to in the publications presented are discussed in the remaining part of this section. They are summarized by what the deviations between farmers' and experts' MMs imply concerning the construction of the SMMA (5.1.1), farmers' present MMs (5.1.2), farmers' future MMs (5.1.3) and what both perspectives show, considering the comparison of present and future MMs (5.1.4).

5.1.1 The construction of the SMMA

Pursuing the first goal in this thesis, a new approach, the Structured Mental Model Approach (SMMA), to interview and analyze farmers' and experts' MMs concerning their livelihood was developed. The results presented in the first publication show that the newly developed approach fulfils mainly three purposes. First the approach includes the local knowledge and the individual context of the persons interviewed by analyzing and comparing livelihood capital definition and weighting trade-offs among experts and farmers with different local knowledge and different livelihood contexts. Second, the approach handles social capital separately and thereby accounts for the specific role of social capital in the livelihood context. Third, the inclusion of all the risks farmers' trade off within their livelihood made the analysis of risk trade-offs in relation to a specific risk possible. This leads to the conclusion that by applying the SMMA the definition and the weighting differences of farmers and experts can be made explicit, such that, if farmers make decisions which are not understandable by experts (such as misuse of pesticides), the decisions can be compared to the differences in MMs between farmers and experts found with the SMMA. Finally, experts may then find other previously unconsidered aspects of reasoning for farmers' decisions.

5.1.2 Differences between farmers' and experts' present MMs

Pursuing the second goal of this thesis, it was shown that farmers' and experts' MMs differ. Considering the differences in MMs may allow to improve pesticide use. Similar findings were shown by Morgan and Fischhoff et al. (2002).

Using the SMMA it was found that experts and farmers differed in the way they defined the livelihood capitals, differed in the weighting by importance of the capitals and had different views concerning the dynamics of the system.
For example farmers and experts differ in the way they define health capital. While farmers define health as being alive, experts define health capital as continuous variable of the physical health status. This difference includes the consequence that as long as health is only impaired, and health protection measures refer to reducing health impairments, health as defined by the farmers is not addressed and the information related to health impairments is ignored.

Additionally, three main explanations for the found discrepancies between the MMs and risk perceptions of farmers and experts where shown. Those explanations were: (i) the role of tradition; (ii) trust in the source of information; and (iii) feedback on knowledge adjustment (see Figure 18).
An example of the role of tradition in farmers' MMs is the finding that farmers agreed that their parents are their main source of information regarding soil and pesticide management. This finding suggests that management habits are passed on from generation to generation and that newly provided information is much more unlikely to be considered than experts might expect.
An example of the importance of trust in the source of information for incorporation of information in farmers' MMs is the finding that farmers try to experience the value of information in order to classify the source of information.
Farmers claimed to have tested both the expensive original products recommended by the pesticide selling companies and the cheaper generic products recommended by pesticide sellers. Their experience from the dosage recommendations was that the generic pesticides need more dosage than the sellers claim while the dosage recommendations from the pesticide companies were correct. Based on these experiences, the farmers see the pesticide companies as in general more trustworthy and information received from pesticide companies as important information to

consider while using pesticides. Similar findings concerning the role of trust were shown by Siegrist and Gutscher (2005) and Siegrist and Cvetkovich (2000).
However, although the generic pesticides require higher doses, they were still perceived by the farmers to be the cheaper alternative to the original products.

An example of the feedback on knowledge adjustment is that only experimentally obtained knowledge feeds back on farmers' MMs. This mechanism implies that information to which no experience can be related evokes an interruption of the feedback mechanism. Such an example is information on protection measures in which farmers are taught to change a habit to avoid a certain not experienced negative effect. Therefore most of farmers' attitudes regarding pesticide protection measures were referenced to self-constructed safety measures confirming their own beliefs and experiences rather than considering experts' safety information.

Moreover additional explanations for differences in MMs were found by analyzing the MMs of farmers' livelihood as a whole, instead of exclusively analyzing the MMs of one specific problem. That is, the deviation of experts' and farmers' MMs were found to be also due to different trade-off effects within the livelihood context, and to different logical-concepts inferred by farmers from one part of the MM of their livelihood to another part.
The demonstrated trade-off effect, explained in more detail in the corresponding publications (Paper 1 and 2), refers to the effect that other risks are seen to be more important than the investigated one. For example financial risk in contrast to health risk. The problem of health risk related to pesticide use is viewed by farmers relative to the financial risk of not earning enough from the harvest if pesticide is used differently from the way it is normally applied. This risk trade-off was found not to be considered by the experts who provide the health and environmental risk related information concerning pesticide use.
A direct consequence of this also explains the observed higher rate of application of pesticides. The perceived higher concerns for financial losses are favored by the lower concerns related to health issues. Farmers decide to apply more pesticides to secure their harvest even when knowing that they are running a higher health risk and a higher risk of contaminating their soils.

Furthermore, in developing and applying the SMMA, it was found that different logical-concepts inferred from some parts of farmers' MM of their livelihood were used by farmers to understand other parts of farmers' MM of their livelihood, e.g. concepts used for understanding natural mechanisms were used to understand health related mechanisms.
For example experienced resistance effects of a pest to a certain pesticide were related to the possibility that a farmer using pesticides without protection equipment could also develop a higher resistance to pesticides and therefore did not need to use any protection equipment in the long run. Additionally recommendations by the experts towards farmers concerning protection during mixing and applying pesticides were translated by the farmers as increase praying to god for health protection and for development of resistance towards health impairments related to pesticides use. Thus the use of a logical concept (such as pesticide resistance) of the natural capital for understanding effects in the health capital explains why farmers still do not use sufficient protection equipment when applying pesticides or mixing pesticide, one of the main factors of misuse of pesticides in developing countries.
The two additional aspects found to explain deviating MMs of farmers and experts, the "trade-off effect" and the "inferring logical-concepts effect", were analyzed further by investigating the risk perception with respect to farmers' desires for the future. The "trade-off effect" became more prominent in future MMs by influencing the information uptake of farmers considering their desires for the future. The "inferring logical-concepts effect" became more prominent in future MMs by influencing the expectations farmers were shown to have about their future.

5.1.3 Differences between farmers' and experts' future MMs

Pursuing the third research goal, the following findings were obtained.
First, differences between farmers' and experts' expectations for the future were found throughout all three parts of the SMMA interview.

Second, farmers and experts differed considerably in the ranking of feasibility and desirability of four predefined futures and on the position of agents in the agent network. For example it was found that farmers and experts have a different understanding of what the scenario cooperative would imply for the farmers' future. Farmers perceived the advantages of being a member of a cooperative as having financial benefits especially in unfavourable market conditions. However, they were dismissive of any dependence and commitment within a cooperative given the bad experiences they had had with the farmers' union. In contrast, experts ranked the union (appraised as a predecessor to a cooperative) as the most important agent in the farmers' future agent network, thereby ignoring farmers' negative experiences with their union. Hence farmers' and experts' differing attitudes toward commitment in a cooperative exemplify a critical hindrance to progress in agricultural development.
Third, in contrast to experts' pessimistic visions, farmers' visions were optimistic, they were convinced that all capitals, except for financial, would improve in the near future. Additionally, it was found that farmers do consider social and environmental threats or hazards in contrast to experts appraisal of farmers' visions. The following example illustrates more clearly the critical implications of these results for the development of agriculture techniques. Farmers were interested in reducing the use of pesticides and therefore showed their readiness to implement ideas of Integrated Pest Management (IPM). In contrast, experts were more negative towards the feasibility of farmers adopting IPM. This attitude divergence leads to the unwillingness of experts to listen to farmers' demands and hinders a constructive development process.

Furthermore, it was found that the revealed inconsistencies of future visions of experts and farmers are also caused by different opinions about who should take responsibility for the knowledge management of farmers.
Technical advisers in the region contracted by governmental or nongovernmental entities were not coordinating their educational interventions. In addition, farmers were increasingly unmotivated to attend several extension programs because they had received contradictory information from different programs. Nevertheless, farmers were convinced that improved and coordinated agricultural support (providing more information concerning agricultural techniques in general and pesticide application in particular) would be crucial for them in attaining their desired future. Hence, farmers place the responsibility for their knowledge in experts' hands. In contrast, experts were convinced that farmers should first be more receptive to new information provided by educational staff before educational efforts could be adjusted to farmers' demands. Therefore experts see farmers themselves as being responsible for their knowledge management.
Therefore the experts who first take responsibility for coordinating farmers' training will be the ones farmers will then depend on. This statement reveals the danger of the increasing dependency of farmers on external experts and offers the opportunity to change farmers' future. One additional finding was that pesticide selling companies currently seem the most willing to fill this responsibility gap. Another point of concern is that if farmers have to pay for their technical advisors, taking responsibility for their knowledge themselves, richer farmers, who can afford to pay for professional technical advice, will be favoured over poorer farmers, thus increasing the gap between the two.

Furthermore the "trade-off effect", mentioned in the preceding section, was found to become more prominent in future MMs by influencing the present information uptake of farmers. This trade-off effect means that expectations for the future were found to influence present information uptake. For example expected future changes in pesticide toxicity were dampening the perception of present toxicity issues. Farmers experienced pesticides as becoming less and less toxic, such that farmers' need for future protection was also expected to become less important; this in turn led to the disregard of current pesticide protection measures and decreased willingness to improve storage facilities.

Moreover expected trade-offs, or trade-offs within present MMs compared to future MMs, were found to influence present information uptake of farmers. Thus not only present trade-offs but also future expectations and expected future trade-offs of farmers' livelihood were found to influence information uptake concerning present risk perception.

For example expected higher prices of pesticides in the future led to an increased interest in alternative crop protection measures in the present. That is, financial trade-offs again influenced the present openness to invest in pesticide knowledge and information concerning risks from pesticide use.
Farmers' perception and experience that new products are more expensive than old ones also gave an explanation why farmers are still using more toxic products than in industrialised countries, and why they seem to be more reluctant to use new products. The reason why they tend to use more toxic products is not because they are more toxic, but because most less toxic products are new and are therefore perceived to be more expensive. Furthermore new products also require to gather new knowledge about how to apply them efficiently which is a time effort most farmers are reluctant to invest.

Moreover farmers expect to need less and less pesticides in the future and are hence even more reluctant to invest in new pesticides they do not expect to need in the far future. This effect is shown by the finding that farmers did not demonstrate any disposition to use new pesticides in order to develop away from pesticide use. Farmers attitude was found to be triggered by one of their most trusted sources of information, their agents of pesticide producing companies.

5.1.4 Differences between farmers' present and future MMs

In pursuing the fourth research goal, the following two findings were obtained. First, the differences found for the individual capitals indicated dependencies of present and future MMs by cause, effect or both. Second, the deviations differed for the capitals analyzed and among the farmers interviewed. These findings led to the conclusion that the comparison of present and future MMs assessed with the same approach gives a measure of how deductive the expectations for the future are built on the perceptions of the present, but also provides a measure of how to weight the present and future embedding of a risk in a MM argument. If in the present and future the same element is argued similarly, then the chances are higher that an improvement in communication can be achieved by a single adjustment of information. But if the arguments differ between present and future, information provision should consider both aspects in order to achieve improved risk perception in the present as well.

Additionally, for the deviations of present and future MMs, the "inferring logical-concepts" effect was found to become more prominent in future MMs by influencing the expectations farmers were shown to have about their future. Just as different logical concepts in MMs of farmers' livelihood were found to influence the different parts of the MMs of farmers livelihood, the mechanisms inferred from the present to predict the future mechanisms were shown to differ within the livelihood capitals and from farmer to farmer. For example, concerning health capital, less logical mechanisms were inferred than in any other capital. Causes and effects were less comparable between present and future such that health capital was perceived by most farmers to be less controllable. Hence information on health capital, even when needed, is less likely to be taken up by the farmers because their attitude to what they could do for their health capital is somehow fatalistic.

The findings concerning the pesticide problem may be expanded to a variety of different important issues in relation to risk information in developing countries such as water management, crop selection, or fertilizer application. What is interesting to note is how future hopes and expectations and positive attitude towards the future trigger the current perception and openness for information.

5.2 Further research

5.2.1 Expanding the SMMA

The SMMA could be expanded by adding the remaining steps of the MMA. The original MMA includes three further steps that have not been considered in this thesis. After comparing experts (step 1) and laymen MMs (step 2) a survey of the MM concepts found should be conducted in the

region (step 3), followed by a communication campaign based on the research findings (step 4), and the developed communications are tested and refined until the communications are fully understood as intended (step 5). These three steps have to be carried out before the insights obtained can be extrapolated to the whole population (Morgan, Fischhoff et al. 2002). Therefore also for the validation of the SMMA and Future-SMMA findings, conducting similar procedures as in the MMA may be envisioned.

An additional measure for extending the SMMA could be to search for patterns in the expressions obtained in the interviews and the use of decoding programs to analyze the interview data. The use of decoding programs, as suggested by Wettokowski, for semi-structured interviews (Wittokowski 1994; Atteslander 2008) may be applied to analyze the data gathered from SMMA interviews. Nevertheless this should be conducted with care, as valuable information may be lost due to the decoding process.

Expert selection is regarded as another measure for improving the SMMA. The selection of the experts constitutes a critical point of the SMMA. Eventhough the experts were chosen as being the ones providing the information to the interviewed farmers it could not always be assured that the knowledge of one expert was consistent with the expertise of all experts. This could be improved by cross checking individual interview results with the derived combined experts' MM. Moreover further research is also needed to avoid the implementation of possible defective experts' knowledge in the adaptation of the information provided for the farmers.

Further, the role of uncertainty of risk should be investigated and could be regarded as a measure to consolidate the SMMA. The uncertainty of risk gives an additional facet to the MM of a person. By incorporating risk into the MM, the outcome of how something works is not certain anymore and forces the person to decide upon something uncertain in outcome. This additional facet makes other aspects of the cognitive process more important, such as feelings and intuition, and makes the decision made by the reasoning process more dependent on the character of a person (risk prone or risk averse). The role uncertainty of risk plays in the process of guessing effects of present mechanisms within the MM of farmers and how uncertainty is interlinked to the trade-off effect among livelihood capitals has been shown to influence the MM of a specific problem. The further investigation of this effect may be achieved by additionally analyzing the risk-character of a person e.g. testing if the person is risk prone or risk averse (Nygren 1977; Brachinger and Weber 1997; Jungermann, Pfister et al. 2005) and incorporating it into the SMMA analysis. The MMs of the farmer could then be analyzed in relation to farmers' character as either risk prone or risk averse.

Finally validation of the newly developed SMMA and Future-SMMA is still an open issue and is essential for the further application of the approach. To perform a validation the SMMA could be applied either in a comparable study region or to a group of farmers with a well known educational background. Moreover the SMMA could be compared to established behavioral assessment tools.

5.2.2 Further investigation of the SMMA's theoretical basis

The dynamic changes of MMs could be investigated by trying to measure how much MMs change due to their investigation. Interesting questions to follow in this would be: Does the conscious or unconscious use of MMs change by analyzing MMs from interviewed subjects? Do the MMs of a specific problem change while being derived by semi-structured interviews with a focus on explaining MMs to interviewers? The influence of the MM analysis may be investigated by comparing farmers' decision-making before and after the SMMA interviews are conducted, or by repeating the SMMA with the same farmers after half a year (one cropping season) and comparing the MMs of both sessions. If the MMs analyzed in the second interview session are found to be more detailed or more explicit considering certain effects (especially in Part II of the interview) and no additional schooling has taken place in the area, then the SMMA is likely to influence the MMs of farmers.

By the same token, the actual role of MMs as a basis for decision-making should be further investigated. Considering that present and future MMs and perception may be interlinked to

influence decision making, the effect of policy measures could also be analyzed. This may be achieved by interviewing a control group of farmers with the SMMA and comparing the MMs of schooled and unschooled farmers. In a first step the relation of MMs and decisions may be further investigated by comparing the decisions of farmers with different MMs and relating the differences in decision to the differences in MMs. In a second step applying the SMMA in a region of educational intervention, possible detected changes in MMs of farmers could be compared to new decisions made by the interviewed farmers so that one could investigate if the change in decision-making could be related to the detected changes in the farmers' MMs.

5.2.3 Application of SMMA in different livelihood contexts

Comparable to the broad field of MMA applications (Maharik 1992; Bostrom, Morgan et al. 1994; Morgan, Fischhoff et al. 2002) the SMMA could be further generalized and applied to other fields of research, e.g. for the assessment of farmers' perception of climatic risk or water management issues. In so doing, the effects of livelihood context to other risks than pesticide application could be investigated. For example, the SMMA has been applied in a research project in Nicaragua introducing a new crop to farmers (Mosimann 2009). Moreover it could be tested in other regions like Asia or Africa where similar risk perception assessments could improve communication in development projects with farmers. Finally the importance of considering livelihood contexts of MMs of a specific problem could also be investigated further by analyzing and comparing MMs of interview subjects from different livelihood contexts, such as employees in a factory with different levels of responsibility or managers or students. Thus the influences of different livelihood contexts could reveal the influences of livelihood context on the structure of MMs.

5.2.4 Use of SMMA data for agent-based modeling

Since derived MMs of farmers are easy to implement for use as a decision basis for agents, they could be used as input in an agent based model (ABM). The causes and effects revealed may be used as rules for the decision-making of agents in the model, for example, an ABM modeling farmers' decision making concerning pesticide use and/or modeling the use of protective equipment. Perceived health risks related to use or non use of protective equipment may be used as decision rule to use or not use protective equipment.

The results could also be used in an ABM coupled with an environmental model, modeling the decision making of farmers concerning pesticide use in relation to environmental effects due to the pesticides applied, as environmental changes and their perception by the farmer are embodied in farmers MMs and therefore also derived by the SMMA results. For example the reaction explaining an increase in pesticide application frequency may be used as a rule for applying pesticides once the environmental model confronts the agent with an increase of pest incidence in his field.

5.3 Relevance of the research findings for policy makers

The findings derived from the SMMA provide a sound basis for the design of better adapted communication and educational programs. Overall, following one of the most important findings of the thesis, risk communication is more effective if it is related to the whole system influencing the subjects' lives. In addition, experts' understanding of the embedding of pesticide risks in farmers' livelihood allows developing strategies for change that consider farmers' priorities and viewpoints. The following specific recommendations are derived from each part of the thesis.

5.3.1 Recommendations derived from present MMs

Different mechanisms were found why the MMs of farmers deviate from experts' MMs. The mechanisms were, as mentioned in previous sections: the role of tradition, trust, the role of

experience with information, trade-off effects among livelihood capitals and the construction of logical concepts by inference from different livelihood capitals. Considering the found differences in MMs and the different mechanisms causing them, the following recommendations for the improvement of information provision can be derived.

- Explain health risks related to pesticide use by taking farmers health definition into account.

This recommendation refers to the found difference in health capital definition. Farmers defined health in a binary way (i.e. being either alive or dead) and farmers stated that religion plays a role for their health capital. In contrast to that experts had a more differentiated perspective of health capital as continuous variable of physical health (i.e. including gradually health impairments and chronic illnesses) and experts health capital definition omitted religious aspects. Therefore newly provided health information should bridge between the experts' continuous and the farmers' binary health definition. Thus experts' information referring to health impairments should pick up possible deaths related to misuse of pesticides as a central theme. Additionally should health impairments explained on the pesticide packaging also be placed in relation to lethal consequences. Furthermore experts should be aware of farmers' religiously coloured health capital definition and stress farmers own possibilities to maintain their own health.

- Be aware of own position in the information chain of farmers and use traditional channels of information.

This recommendation refers to the important role of parents as main source of farmers' knowledge conserving pesticide management. Therefore experts' awareness of their position in the information chain of the farmers means that experts should acknowledge the important role of farmers' parents as a usable traditional channel of information. Thus experts should include not only younger farmers in information campaigns but also elderly members of farmers societies. Those elderly farmers can than act as multipliers of experts' information by passing the information on to their children.

- Provide reproducible and reliable information

This recommendation refers to role of trust of farmers towards the informants related to contact intensity and experience gained with the provided information. Therefore we recommend in particular to

  - Provide information by means of practical experience.
  - Establish credibility.
  - Maintain a high contact intensity to farmers.

New information should mostly be connected to an experience (or practical experiment). Whenever a practical experiment cannot be provided, the missing experience must be acknowledged and discussed with the farmer.
The trustworthiness of the informer and the experience of the farmer dealing with the information, have also to be considered and wherever possible improved to achieve a higher uptake of health safety information concerning pesticide application.
The contact intensity should be cultivated, in view of the found mechanisms within the social capital of farmers that demonstrate the importance of frequent visits and importance of the reliability of the information provided to farmers in order to establish a persistent and effective communication among farmers and experts.

- Consider the revealed trade-offs of farmers' livelihood and add them to the provided information.

This recommendation refers to the importance of trade-offs considered by farmers in their reasoning and decisions. Thus experts should consider for example financial aspects when providing health related pesticide information, and compare health risks with financial risks.

5.3.2 Recommendations derived from future MMs

Comparable to participatory approaches stressing the importance of considering local perspectives in order to make development projects more successful (Scoones and Thomson 1994; Höppner 2007), the findings here considering local perspectives from the viewpoint of the future provide further ways to improve the success of development plans. Thus the inconsistencies in future visions of experts and farmers found are used to derive the following recommendations to improve communication in relation to development projects.

- Refer to farmers' expectations when providing information.

This recommendation refers to expectations found with the Future SMMA such as the expectation of farmers that pesticides are going to be less toxic in the future and that therefore they can disregard protection measures. This expectation should lead to a policy recommendation which takes up farmers expected decreasing need for protection measures and guides farmers to reconsider the actual need for more protection measures in the present.

- Consider general (positive or negative) attitudes towards future development and opinions about who should take responsibility of information supply.

This recommendation refers to the findings that inconsistencies in MMs were shown to be due to diverging attitudes towards future scenarios and differing opinions about who should take responsibility for the knowledge management of farmers. These two aspects have to be considered in the successful design of agricultural development plans. Information campaigns should not only provide information but also encourage farmers to realize their own responsibility and influence on future developments. For example could farmers be taught to help in the coordination of trainings by being able to suggest topics for trainings in their. Furthermore before each training session farmers expectations concerning the training should be monitored and the training tailored accordingly.
An additional point to consider hereby is that if farmers are left to hand the responsibility for their information supply over to external entities, the experts who first take responsibility for coordinating farmers' training will be the ones farmers will then depend on. This statement implies a danger of increasing dependency of farmers on external experts but also offers the opportunity to change farmers' future by providing experts with an attractive possibility to step into a responsibility gap.

- Develop awareness of own future perspectives and the constraints derived from these before providing information to farmers.

This recommendation refers to the findings that show that by having a pessimistic attitude experts seem not to provide the farmers with all necessary pesticide information, and that therefore expected future possibilities also affected experts' knowledge supply. Not considering farmers' positive attitudes, experts run the risk of not considering the possible openness of farmers towards alternative information.

- Investigate and consider farmers' desires for the future before and while trying to provide new information for the farmer.

This recommendation refers to the finding that farmers, desiring different futures, are not open to processing the information provided that is of less interest to them. The recommendation can be performed by conducting a Future-SMMA before providing new information to a farmers group. For example the finding that farmers where interested in Integrated Pest Management (IPM) should be taken up by experts as a chance to provide IPM information to farmers together with actual protection measures applying pesticides in order to bring along a safety information together with some technical information that farmers where actually interested in.

5.3.3 Recommendations derived from present and future MMs

The inconsistencies of present and future MMs reveal mechanisms of learning processes of individuals and the role of future MMs for those learning processes. Hence the method constitutes a way to learn by which measures the MMs are constructed and a method to determine how they should or could be altered. According to Harries (2003) and Chermack (2006) scenario planning has a utility in extracting, developing, examining and refining individual theories-in-use. Hence rules of thumb and decision-making based on rules of thumb (Goldvarg and Johnson-Laird 2001) could be improved by deducing policy measures from the results obtained in the study. Thus to improve decision-making based on rules of thumb the following recommendations were derived from inconsistencies of present and future MMs.

- Identify farmers present and future MMs inconsistencies and present information tailored to the recipients' MMs inconsistencies (effect-focused vs. cause-focused farmers).

This recommendation refers to the different found features of the MMs revealing learning processes of the interviewed farmers. Therefore we recommend in particular that

  - Information addressed to effect-focused farmers should emphasise the effects of certain mechanisms presented in the information.

Effect-focused farmers, for example farmers having stated observed effects like burning of plants, should be provided with information about health effects when not using protection measures like nausea and skin rashes.

  - Information addressed to causes-focused farmers should emphasise the causes triggering certain effects in mechanisms presented in the information.

Cause-focused farmers, for example differentiating present and future classes of toxic pesticides, should be provided with information about what degrees of nausea or skin rashes appear when farmers use pesticides omitting protection measures.

5.3.4 Further recommendations

- Develop new pesticide use strategies in expert-farmer teams.

This recommendation refers to the finding that the application of the SMMA enables to derive an understanding of farmers' thinking, suggesting that it should be possible to develop strategies in expert-farmer teams. The workshops conducted with the interviewed farmers and experts provide a preliminary basis with which to validate these suggestions. The MMs of farmers and experts should therefore serve as a commonly agreed communication platform.

- Measure the effect of trainings by applying the SMMA.

The SMMA developed and presented in this thesis is a method to be applied in the area of information provision to measure the effects of trainings and improvements of trainings. Thereby the SMMA provides a tool to measure the success of educational programs from information provision to information uptake and to information-in-use, when applied before and after an informational or educational campaign in order to measure the possibly achieved differences in MMs of the participants. Therefore the SMMA can be used to measure the change in MMs of farmers in relation to the divergence from experts' MMs throughout an educational program.

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7 Curriculum Vitae

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Education

1990-1995	A-levels in economy (Type E) at Kantonsschule Heerbrugg, Switzerland
1995-1998	Studies in Physics at Swiss Federal Institute of Technology Zurich (ETHZ) (4 semester in Zurich and 2 semester, with Erasmus Student Exchange Program at the Strathclyde University Glasgow, Scotland)
1998-2003	Studies in Environmental Sciences at Swiss Federal Institute of Technology Zurich (ETHZ)
	Degree: Dipl. Umwelt-Natw. ETH
	Diploma thesis at the Institute of Atmospheric and Climate Science (IAC), Title of thesis: „Klimaszenarien für Starkniederschläge in Europa, eine Analyse von regionalen Klimamodellen mit Extremwertstatistik“
2005-2009	Dissertation. Title of thesis: Understanding the Difference between Farmers' and Experts' Livelihood Perspectives: The Structured Mental Model Approach (Case study: Pesticide use in Vereda la Hoya, Colombia), at Chair of Human and Environment Systems (HES) ETHZ, under the leadership of Dr. Claudia R. Binder
Since 2006	Change of PhD to the Chair of Social and Industrial Ecology at the Department of Geography, University of Zurich, under the leadership of Prof. Dr. Claudia Binder
Since 2005	Teaching assistant of the lecture “Modelierung Mensch Umwelt System I” at University of Zurich and ETHZ, and Co-supervisor of Diploma, Semester, Master and Bachelor Theses at University of Zurich and ETH

8 Additional publications and presentations

Publications

Binder C.R. and Schoell, R. (in progress) Mutual understanding of pesticide application systems: Results from two workshops emerging from SMMA and Future-SMMA, Journal: *Environment and Behaviour, Conservation and Behaviour or Ecology and Society.*

Schoell, R. (in progress) Report for Syngenta: Application of the Structured Mental Model Approach (SMMA) to analyze the impact of Syngenta pesticide trainings on farmers in Boyaca.

Schoell, R. (in progress) Manual of Structured Mental Model Approach (SMMA): Tool to assess the Mental Models of Experts and Farmers.

Presentations

Schoell, R. and Mosimann, A. (2009) Workshop*:"Taller Beneficios de las leguminosas en sistemas mixtos con pequeños productores en las laderas de Centro América", 29.01.2009*; Sta. Teresa (Nicaragua)

Schoell, R. (2008) Perspectives of Farmers and Experts regarding future agricultural development: Results from a Future Structured Mental Model Approach; *2nd International Sustainability Conference, Creating Values for Sustainable Developement*, 21-22 August 2008, Basel, Switzerland.

Schoell, R. (2007) System perspectives of Experts and Farmers regarding the role of livelihood assets: Results from a Structured Mental Model Approach; *16th Society for Risk Analysis (SRA) Europe Conference, Building bridges: Issues for future risk research.,* 17-19 June 2007, The Hague, the Netherlands.

Schoell, R. (2006) Analysis of diverging system perspectives for achieving sustainable agricultural production, *Tropentag 2006, International Research on Food Security, Natural Resource Management and Rural Development,* 11-13 October 2006, Bonn, Germany

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Schoell R., Binder C. R. (2008) Comparing System Visions of Farmers and Experts; *International Conference on Research for Development (ICRD 2008)*I, 2-4 July 2008, Bern Switzerland.

Schoell R., Binder C.R. (2007) Perspectives of Farmers and Experts regarding future agricultural development: Results from a Future Structured Mental Model Approach; *Tropentag 2007, Conference on International Agricultural Research for Development,* Universitiy of Kassel-Witzenausen and Universitiy of Göttingen, 9-11 October 2007, Witzenhausen, Germany.

Schoell R., Binder C.R., Diaz J. (2006) Analysis of diverging system perspectives for achieving sustainable agricultural production (Winner of poster competition); *Workshop on: Soil protection for natural resource protection, Monte Veritá,* 1-5 October 2006, Ascona, Switzerland.

Schoell R., Binder C.R., Diaz J. (2006) Analysis of diverging system perspectives for achieving sustainable agricultural production; *Gordon Research Conference on Industrial Ecology*, 6-11 August 2006, Queens College, Oxford, UK.

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Appendix

Structured Mental Model Approach for Analyzing Perception of Risks to Rural Livelihood in Developing Countries

Journal: *Sustainability (Vol.2, 2010, pp. 1-29; doi:10.3390/su2010001)*

Authors: Binder, C.R. and Schoell, R.

[Paper 1]

System Perspectives of Experts and Farmers Regarding the Role of Livelihood Assets in Risk Perception: Results from the Structured Mental Model Approach

Journal: *Risk Analysis (Vol. 29, No. 2, 2009, pp. 205-222)*

Authors: Schoell, R. and Binder, C.R.

[Paper 2]

Comparing system visions of farmers and experts

Journal: *Futures (Vol. 41, No. 9, 2009, pp. 631-649)*

Authors: Schoell, R. and Binder, C.R.

[Paper 3]

Comparison of farmers' mental models of the present and the future: A case study of pesticide use

Journal: *Futures (in press, 2010; doi:10.1016/j.futures.2010.04.030)*

Authors: Schoell, R. and Binder, C.R.

[Paper 4]

Paper 1

Structured Mental Model Approach for Analyzing Perception of Risks to Rural Livelihood in Developing Countries

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Article

Structured Mental Model Approach for Analyzing Perception of Risks to Rural Livelihood in Developing Countries

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Abstract: This paper presents the Structural Mental Model Approach aimed at understanding differences in perception between experts and farmers regarding the various livelihood risks farmers are confronted with. The SMMA combines the Sustainable Livelihood Framework with the Mental Model Approach and consists of three steps: (i) definition and weighting of different livelihood capitals; (ii) analysis of livelihood dynamics, and (iii) definition of the social capital by means of agent networks. The results provide a sound basis for the design of sustainable policy interventions such as communication and educational programs which consider farmers' priorities and viewpoints.

Keywords: mental models; sustainable rural livelihood; livelihood risks of farmers; developing countries

1. Introduction

This paper provides a methodological approach to analyzing differences in risk perception between farmers and experts in developing countries. The approach combines the Sustainable Livelihood

Framework (SLF) [1] with the Mental Models Approach (MMA) [2], allowing greater understanding of: (1) farmers' risk perception in the context of their livelihood, (2) the differences in risk perception between farmers and experts, and (3) priorities and trade-offs of risk strategies selected by farmers.

Sustainable development of small-holder farmers in developing countries depends highly on their ability to cope with several risks affecting their livelihood [3,4]. First, they have to deal with environmental risks such as climatic risks (rainfall in rainfed agriculture), soil erosion, and pest infestations [3-6]. Second, they are also confronted with health risks, such as malnutrition due to an imbalanced diet, and neurological impairments, nausea, blurred vision, *etc.* resulting from the improper application of pesticides (lack of protection, quality and quantity of the products chosen) [7-10]. Third, they have to deal with financial risks, that is, with the proper marketing of their products, regional and national price volatilities, and access to credit [3,11]. Finally, a further often-neglected risk is the loss of social networks, that is, loss or change of social status, loss of friends or family [3,5].

Several authors have emphasized that for developing sustainable risk coping strategies, the risks small farmers in developing countries are confronted with have to be studied in relation to their livelihood [12-14], even if the focus is only on specific risks such as environmental risks, e.g., soil erosion [3-6]. One approach that has been developed to provide a more systemic and holistic perspective on farmers' strategy selection is the SLF [1]. The framework states that farmers' livelihood depends on their knowledge and ability to use their assets in such a way that the family can make a living, meet their consumption and economic needs, cope with uncertainties and respond to new opportunities [15,16]. Typically, human, physical, financial, natural and social capital are considered when studying farmers' livelihood [1]. The stock of capitals is specific for each farmer, constraining or enabling his/her decisions and actions [12]. The latter, in turn, impinge on the stock of their capitals, creating a feedback loop. According to Scoones [17] "a livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resources base". Please note that Scoones *et al.* utilize the term natural resources base as a synonym to natural capital base. The results from livelihood analyses have been used for evaluating and developing sustainable rural development programs at a micro level [1,16,18-20].

Several methodologies for assessing farmers' livelihood have been developed by different research groups as well as international agencies [1,16,18,20,21]. In most of the methodologies, farmers assets and capabilities are investigated through a set of participatory tools (interviews, focus groups, [19] leading to an assessment of farmers livelihood situation. However, the SLF [1] and the developed methodologies have two problems in common.

First, the SLF [1] and related methods do not include the link between farmers' assets and their decision-making in their analyses, neglecting to some extent farmers' local knowledge and their view on their own livelihood. Even though the livelihood approach would suggest that farmers with the same set of assets would take similar strategic decisions, de Haan and Zoomers [16], found that this was not the case. The knowledge of farmers' assets proved not to be sufficient to understand their decision-making on the allocation of their capitals and thus to provide a basis for developing strategies for a more sustainable livelihood. There are two explanations for these findings. On the one hand, de Haan and Zoomers argue that variables such as geographical settings and access to markets might

affect the allocation decisions and propose the study of trajectories to foster the understanding of current decisions based on former ones. On the other hand, psychological studies show for cases of reflective decisions that, the prioritization of the assets, the way farmers see their interaction, and the risks perceived might significantly affect their decisions and the potential livelihood pathways [22]. That is, the way farmers perceive their livelihood, and how they conceptualize the livelihood dynamics has a direct influence on their decision-making and behavior [21]. Furthermore, their knowledge of the system and their perception of specific risks is likely to significantly differ from the one of experts. This issue has been largely investigated with respect to soil management and local soil characterization systems [23-27]. Müller-Böker [23], for example, found that local farmers in Nepal characterized and evaluated soil quality according to its agricultural relevance, while scientists would primarily focus on morphogeneric criteria. Abdulai and Binder [28] showed for the case of Nicaragua that farmers' decisions on the amount of pesticides to be applied significantly depended on earlier managerial decisions taken, such as burning or not burning the crop residues on the field. Thus, farmers do have a specific system knowledge from which they draw their conclusions and balance their risks, and in which they embed their decision-making. This knowledge and its relationship to decision making has rarely been included into farmers' livelihood analysis. Furthermore Schoell and Binder [29] showed that differing risk perceptions and priorities among the various capitals of farmers' livelihood between experts and farmers might lead to misunderstandings and failure of educational interventions. Feola and Binder [30], additionally showed that social norms are a key factor affecting farmers' decision whether to use or not use protective equipment when applying pesticides. These results imply that for an intervention to be successful on the one hand criteria as land tenure, education, technical assistance, are relevant. On the other hand, farmers' perceptions, their system understanding as well as the social norms prevalent in the region have to be considered.

Second, it has been shown that social capital can play an important role with respect to the access to individual capitals (e.g., natural or financial capital) [21]. For example, farmers with a higher integration into a social network are able to develop out of poverty, where as others are not as successful [16]. Still, the social capital has not been analyzed separately and in depth within the livelihood approach and to our knowledge the differences of how experts see the social network farmers are embedded in and how farmers themselves see their network, as well as the consequences of these differences have not been investigated so far.

Therefore, relevant research questions are: What is farmers' understanding of their livelihood? How do they conceptualize and balance the different risks and dynamics of their livelihood? How does their system understanding diverge from that of experts? What role does social capital play in the eyes of experts and farmers?

The analysis of mental models (MMs) has proven useful for understanding the underlying thinking of persons and in determining the difference between laymen's and experts' risk perception [2,31]. MMs are defined as intuitive theories or tacit maps which people construct and hold in their long-term memory. These theories are used in the everyday decision-making process to interpret new situations and react accordingly, and to make predictions or develop scenarios on future developments [22,32-35].

Drawing on the concept of MMs, Morgan [2] developed the Mental Models Approach (MMA). The main goal of the MMA is to (i) analyze differences in risk perception among experts and laymen

(e.g., identifying differences in how experts and laymen understand and interpret exposure, effect and mitigation processes [36]); (ii) identify misconceptions in system understanding [2,37] and (iii) develop adequate and successful risk communication tools [2,37].

The MMA has been applied in diverse fields of research, such as risk communication [2,37-40], system dynamics [8]; and environmental decision-making [41,42], as well as comparisons of shared and team mental models in organizations [43]. However, two main limitations of the MMA have been identified which might be particularly relevant if this approach is to be used to understand the differences in risk perception between experts and farmers in developing countries and develop sustainable intervention strategies [44,45].

First, the system boundaries are often set too narrow. Researchers often investigate experts' and laymen's MMs with respect to their perception of a specific risk, neglecting its relation to other risks prevalent in the system laymen live in. Therefore, the focal consequences are mostly discussed (*i.e.*, the immediately apparent consequences), whereas indirect consequences are not studied [45]. In the case of farmers, the different types of risks they are confronted with make it necessary to broaden the system boundaries to allow for including the different livelihood capitals and the analysis of risk trade-offs and thus allow for a more holistic design of strategies [6]. Furthermore, Murphy and Gardoni [45] suggest to use assets and capabilities as a means for communicating possible consequences of risk management strategies to lay-people.

Second, the individual contexts, motives, and values are rarely included in the analyses. When expert and layman risk perceptions are compared, their differences are related mostly to differences in knowledge and expertise, whereas, individual contexts, motives, values, or even traditions are not included either in the analysis or the interpretation of the results [44,45]. In the case of farmers in developing countries, this issue is important, as in rural areas of developing countries differences in risk perception are likely to be related to or induced by cultural beliefs and traditions [23-25,46-48].

In this paper we propose a methodology, the Structured Mental Model Approach (SMMA), which combines the SLF [1] with the MMA [2] to analyze the differences in risk perception between farmers and experts in rural areas in developing countries. With this methodology we aim at building a base for designing strategies for more sustainable rural livelihoods. In particular we aim at contributing towards:

1. Understanding farmers underlying mental models and perceptions. In particular, understanding the relevance of perception of a specific risk in relation to farmers' livelihood.
2. Comparing the mental models of experts to the one of farmers for identifying potential misunderstandings.
3. Analyzing the sources of potential misunderstandings between experts and farmers.
4. Supporting the development of intervention strategies, considering farmers' mental models and their differences to the one of experts.

The paper is organized as follows: First, we present a conceptual framework which combines the psychological factors with the socio-cultural factors involved in farmers' decision making. Second, we show how this conceptual framework can be operationalized, taking account of the different degrees of literacy between experts and farmers in developing countries. The operationalization and implementation is illustrated with a case study about pesticide management risks in the highlands of

Colombia, South America and a case study on soil conservation measures in Nicaragua. Finally, we discuss the implications of the presented approach and conclude.

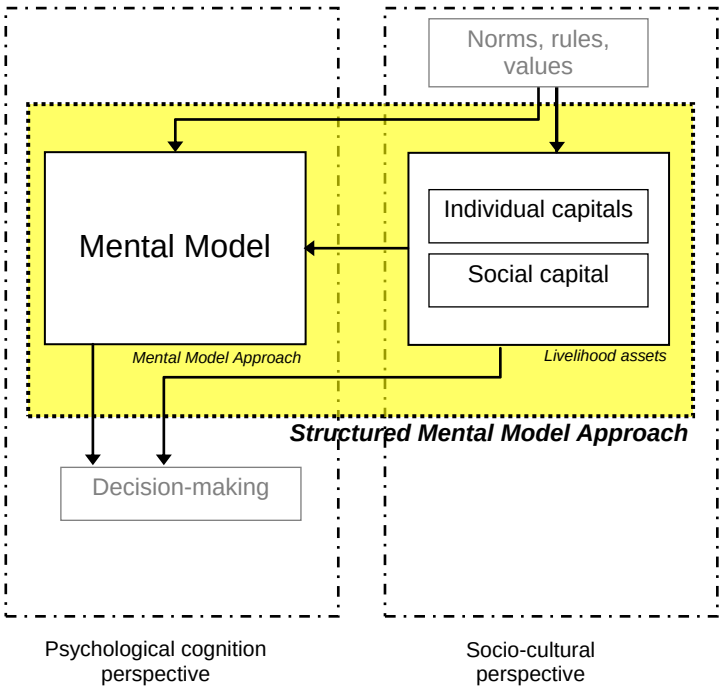
2. Conceptual Background

From a conceptual point of view the SMMA combines concepts emerging from psychological cognition perspectives as is the MMA with socio-cultural perspectives as is the SLF. The conceptual framework (Figure 1) of the SMMA provides a systemic perspective for relating farmers' MMs to their livelihood, social structure, and decision-making. It depicts on the one hand the factors affecting farmers' mental models and consequently his/her decisions. On the other hand the models integrated in the SMMA are presented.

2.1. The Psychological Cognition Perspective

On the left, the contribution from cognitive psychology is depicted. The perception of the livelihood, an intervention or a specific risk to farmers 'livelihood is part of farmers' MMs [2,49]. These MMs feed together with other variables, such as land size, access to credit, *etc.*, into farmers' decision-making. Please note that the MMs represent the way in which farmers perceive their livelihood and do not have to be identical with what one would objectively measure. That is, farmers with the same assets can have a different view on them being wealthy or poor.

Figure 1. System border of the MMA and the SMMA (left: psychological cognition perspective; right: socio-cultural perspective; Individual capitals consist of human, physical, financial, and natural capital).



2.2. The Socio-Cultural Perspective

On the right, the components of the conceptual framework (Figure 1) related to socio-cultural research are shown. Socio-cultural research considers that cultural assumptions and normative values (components of the social structure) across social groups are important bases for forming the ideas about livelihood, its risk and risk management [49]. Hereby we base ourselves on the concept of the "risk society" as described by Giddens [50], in which he investigates the impact of culture and cultural change at the individual level. Giddens structuration theory [51] states that individuals are influenced by social structure (e.g., social norms, values and rules) in two ways. First it affects them directly as individuals within their human capital as they are part of a culture and have culturally specific traditions (in Giddens terms: siginification [51]). Second, it affects the way farmers perceive their livelihood and hence their MMs (see above). Similarly Smith and Collins [52] state that the social context shapes the cognition of individuals and so their MMs.

The SLF provides an analytical approach to structure farmers' livelihood assets. Individual capitals as part of farmers' livelihood are defined as the assets and capabilities farmers have access to. They impact on their thinking and perception given the social structure they are embedded in [1,21,53,54]. In our approach, the individual and social capitals are constituents of the MMs built for analyzing risks. Therefore, the relevance of each individual capital for farmers' livelihood, their interactions, and their relation to the selected risk should be studied. Based on the SLF [1], we suggest on including human, natural, physical, and financial capital in the analysis (Table 1).

Table 1. Definition of the four individual capitals and social capital and their relation to risks small-holder farmers are confronted with.

Capital type	Definition	Related risk
Human capital	People and their ability to be economically productive. It includes educational level, skills, experience, knowledge, creativity and innovativeness [16] Education level and health status of individuals and populations [55]	Health risks
Natural capital	The natural resource base available for pursuing an agricultural activity. It includes land and soil quality; access to water, *etc.* [1]. Natural resource base (land, water, trees) that yields products utilised by human populations for their survival [56]	Environmental risks
Financial capital	Stocks of cash that can be accessed in order to purchase either production or consumption goods, and access to credit might be included in this category [56]	Financial risks
Physical capital	Assets brought into existence by economic production processes, for example, tools machines and land improvements like terraces or irrigation canals [56]	
Social capital	Process and condition of social networking among people that lead to accomplishing a goal of mutual social benefit, usually characterized by trust, cooperation, involvement in the community, and sharing [57,58]	Loss of social status and network

Alternatively, one could consider of dividing the human capital into human capital (only related to education, tradition, *etc.*) and health capital to be able to determine effects between education and health as suggested by Schöll and Binder [29].

In contrast to the SLF, in the SMMA we look at social capital in a different way as at individual capitals, as:

- it includes relations between people rather than property owned by people
- it can usually be considered a public good shared by a group of people
- it is created by mutual effort over time of different people

Social capital is thus defined as the process and the condition of social networking among people that leads to accomplishing a goal of mutual social benefit, usually characterized by trust, cooperation, involvement in the community, and sharing [57,58] (Table 1). It is a product of culture and social norms within a society.

In the SMMA we specifically look at social capital in a relatively narrow sense, considering linkages, one form of social capital, which includes the relations between social strata, and reflects power relations [59]; see [57,60] for detailed definitions on social capital.

2.3. Considering the Different Literacy Levels in Less Developed Countries

In less developed countries one often has to deal with illiterate farmers or farmers with only a few years of education. We designed the SMMA so that the different levels of schooling and capacity of abstraction can be accounted for. Furthermore, the mental models elicited differ in their complexity as follows [32]:

Monadic models and set-theoretic models [32], aim at representing differences in the definition of the livelihood capitals

Two relational models [32] lead to (i) an influence diagram [2] of the interrelations between the livelihood capitals, and (ii) an agent network of the agents influencing farmers.

3. The Structured Mental Model Approach (SMMA)

In the following the specific procedure of the SMMA is described. In each section specific results are presented and their contribution to risk reduction and intervention planning is shown.

The SMMA is divided into three parts (Table 2):

Part I: Definition and weighting of the Individual Capitals

This part aims at understanding whether the definition of the livelihood capitals is the same for experts and farmers and how each group prioritizes one livelihood capital over the other.

Part II: Analysis of the Livelihood Dynamics

This part aims at understanding the way farmers perceive the dynamics of the system they are embedded in. The understanding of farmer underlying logic is essential for explaining them, what the

contribution of a specific technology to their livelihood might be. The comparison to experts view makes potential misunderstandings explicit.

Part III: Definition of the Social Capital

This part depicts the agents' network of farmers. The closer the farmer views the intervening institution relative to other agents, the higher the probability of a successful intervention might be. The results provide furthermore the basis for selecting collaboration partners.

Table 2. The assembly methods utilized in the SMMA.

	Experts model of farmer's livelihood	**Farmers' model of their livelihood**
	Influence diagrams of system elements and agents	Open-ended questions of system elements and agents
Part I	• Listing of relevant capital group elements • Weighting of the capitals	• Grouping of the elements assembled by the experts in four capitals • Weighting of the capitals
Part II	• Showing how the elements are related	• Answering open-ended questions on the relations found by the experts
Part III	• Listing the relevant system agents • Designing an agents network	• Designing an agents network with the agents listed by the experts

In the following, we present the general approach. It is illustrated with results of two case studies in Latin America. One deals with pesticide management in Boyaca, Colombia [29]. The other studies the implementation of Canavalia as an erosion minimizing and fodder plant in Nicaragua [61].

3.1. Selection of Experts and Farmers

In order to cover all the perspectives of farmers' livelihoods, experts with different fields of expertise, e.g., agricultural economists, agronomists, *etc.* as well as experts of the specific risk analyzed should be selected. It is essential that experts' areas of expertise overlap, so that the robustness of the developed expert mental model can be guaranteed (Table 3).

Table 3. Example of selection of experts depending on their specialization (one expert can cover several capitals).

Human	**Physical**	**Natural**	**Financial**
Agronomist	Agronomist	Agronomist	Agronomist
Local technical assistance	Local technical assistance	Environmental engineer	National economist
Regional technical assistance	Regional technical assistance	Toxicologist[a]	Local economist
Medical doctor[a]			Pesticide seller[a]
Toxicologist[a]			
Teacher			

a: specific experts concerning pesticide risk analysis.

For the selection of farmers a purposeful sampling has to be carried out. Thereby, farmers with different levels of human, natural, physical and financial capital, have to be selected. This will allow us to analyze the variance between farmers' mental models and to understand whether the differences between farmers and experts are larger then the ones among farmers (Table 4).

Table 4. Examples of possible capital states of the interviewed farmers.

Capital	High (state)	Low (state)
Human	• Education: at least finished primary education • Health: no severe health problems	• Education: no formal education • Health: severe health problems
Natural	• Soil: fertile soils • Slope: low • Forest: owns land with natural forest	• Soil: low soil fertility • Slope: high • Forest: does not own any natural forest
Financial	• >10 ha of own land • Good access to credit	• Landless farm worker • No access to credits
Physical	• Access to paved road, irrigation system, machinery	• Geographically isolated farmer, no agricultural machinery
Social	• Status: community leader	• Status: isolated member of the community

The size of the sample depends on the amount of interviews required until a drop off new concepts is encountered. Applying the MMA typically 20–30 interviews are conducted within a population group with relative similar beliefs [2]. Maharik [62] experienced that the number of new concepts encountered in mental model interviews often increases rapidly for the first 10–15 interviews approaching an asymptote around 20–30 interviews. During the farmers' interview in the case of Schöll and Binder [29] for Colombia and Mosimann [61] for Nicaragua, a drop-off of new concepts was observed after 4–5 farmer interviews. Therefore, if the characteristic drop off of new concepts is encountered after 5 or 10 interviews, a sample size of 10 or 20 persons is recommended, respectively.

3.2. Implementation of the SMMA

The interview is carried out in four steps. Introduction to the research; Part I: Definition and weighting of farmers' individual capitals; Part II: Interaction and dynamics between the capitals; and Part III: Social capital.

3.2.1. Introduction to the Research

The introduction to the research includes the following steps: (i) presentation of the interviewer and research, (ii) recording of their personal working background (experts) or socioeconomic situation (farmers), and (iii) overview of the interview.

3.2.2. Part I: Definition and Weighting of Farmers' Individual Capitals

The goal of this part is (i) to ascertain how farmers and experts define and weigh farmers' individual capitals and (ii) to analyze the differences between these definitions. Differences in capital definition between farmers and experts already provide insights into potential origins of misunderstandings when developing a risk communication strategy or implementing a new technology. Differences in the ranking of the capitals provide an indication on the divergent perception of the importance and consequently the perceived risks to farmers' livelihood capitals. We hypothesize that the higher the weighting of the capital is, the more farmers/expert will do to avoid risks to that specific capital.

Interview

The expert interview. In the expert interview, first, experts are given a definition and two example elements for each of the four individual capitals. Then they are asked to determine additional elements that will complete the set of elements of each capital group. The result is a set-theoretic model for each type of capital [32]. Finally, experts are asked to weight the capitals considering their relevance for farmers' livelihood. We suggest using a simple rating procedure, in which the experts interviewed are asked to rate the capitals between 1 and 4 (e.g., 1: most important to 4: least important capital group; see Table 5 for an exemplified interview). A more time-consuming and sophisticated option would be to perform an Analytical Hierarchy Process (AHP). AHP is an approach for weighting criteria in multi-criteria decision-making analysis, which is based on pair-wise comparisons of two criteria [63]. AHP requires that weighting criteria be defined and has the advantage that it encourages people to make clear statements on trade-offs between the criteria. An advantage of AHP is that it also provides an inconsistency check, which makes it possible to identify persons who were not able to perform the weighting correctly.

Table 5. Examples of questions posed in Part I of the expert interview (example for pesticide related health risks).

Part of the interview	**Examples of questions**
Definition of the capitals	Here are the four capitals chosen to define farmers' livelihood. They are defined as follows (see Figure 2). Please complete the elements belonging to each type of capital.
Ranking of the capitals	What role do the capitals play regarding farmers' use of pesticides? Please rank the capitals with respect to their relative relevance for farmers and explain. (1 = highest relevance; 4 = lowest relevance) Please consider their short- & long-term relevance.

The farmer interview. As preparation for the farmers' interview, we suggest taking photographs representing the region-specific pooled elements elaborated by the experts (Table 6). In a Latin

American context, we recommend photographs over pictograms or cartoon-like figures as farmers do not necessarily relate pictograms to their everyday reality.

Table 6. Example of an element consolidation and its photographic representation (example from case study Vereda la Hoya, Schöll and Binder, 2007).

Elements named by experts		Consolidated element		Regional relation		Photograph
• Religion • Ideology • The prayer	→	Religion	→	Visualization of religion in Vereda la Hoya	→	Communal church farmers go to 

The farmer interview contains one step more than the expert interview. First, the capitals are defined by utilizing the same examples as in the expert interview. Second, farmers are shown the photographs of the elements and asked to define what they see in each picture (obtaining a monadic model [32]). Then they are asked to place the photographs in the four explained capital groups, obtaining a set-theoretic model (Table 7). For each placement they are requested to justify their choice, so that potential differences between experts and farmers can be explained. Finally, farmers are asked to rank the four capital groups in order of importance (e.g., 1: most important to 4: least important capital group) regarding the sustainability of their livelihood. If an AHP is to be applied, it has to be taken into account that illiterate people in developing countries are more likely to give inconsistent answers then people in developed countries [64].

Table 7. Examples of questions posed in Part I of the farmers' interview.

Part of the interview	Examples of questions
Definition element Photographs	Here are the four capitals chosen to define your livelihood in four groups. They are defined as follows… Please sort the following photographs into these four groups, commenting first on what you see in the photograph and second explaining why you chose to place the photograph in a specific group.
Ranking of the capitals	What role do the capitals play regarding the *specific risk*? What role do the capitals play regarding your livelihood? Please rank the capitals with respect to their importance for you and explain. (1 = highest relevance; 4 = lowest relevance) Please consider their short- & long-term relevance.

Analysis

The expert interview. In a first step, the elements named by the experts to define the individual capitals are analyzed and multiple mentioning and synonyms summarized. This leads to a consolidated

list of region-specific pooled elements for each capital group, which builds the expert part of the capital definition. The elements could be presented as in Table 8 where the capital characterizing elements named by experts are sorted and marked in grey.

Regarding the ranking, it is aimed at obtaining one expert ranking. If deviations between experts emerge they should be discussed. Persisting deviations should be noted and considered when interpreting the differences in ranking between farmers and experts.

The farmer interview. In analogy, for farmers' interviews, the statements of what the farmers recognized on the photographs are consolidated. Subsequently, the total number of naming of each element to define each capital is inputted into the capital definition table (Table 8). The rankings of all farmers are summarized by counting the number of votes for each capital being placed to a specific rank. The capital with most votes for the nth rank is ranked on nth position.

Table 8. Example of capital definition by experts' and farmers' allocation of the elements to the capital groups (Fields in gray indicate expected placement by experts) adapted from [61].

Experts	**Element**	**Farmers' element allocation to capital group**			
		Human	**Physical**	**Natural**	**Financial**
Human capital	Technical assistance	2		6	2
	Nutrition	2	5	3	
	Politics	5	2		3
Physical capital	Pesticides		2	6	2
	Fertilizer		2	5	3
	Seeds		3	6	1
Natural capital	Canavalia		5	2	1
	Maize harvest		5	3	2
	Livestock		2	3	5
	Soil	1	4	5	
	Bean harvest			6	4
Financial capital	Bank		1	4	5
	Tobacco		3	2	5
	Costa Rica	1	1	1	7

Results and Interpretation. Table 8 shows exemplarily results obtained when analyzing the capital definition of experts leading and farmers participating in a soil conservation project [61]. One of the differences found, was that experts allocated technical assistance as being part of the human capital, since the activities of technical assistance should increase farmers' human capital. Farmers, instead, used this element to define natural capital. Their explanation was striking: the technicians were telling them exactly what to do and how to work with their soil, but they were not teaching them anything, suggesting a paternalistic type of intervention [65]. This example shows very clearly that the definition

of the capitals and moreover the differences between farmers and experts give indications on potential weaknesses within the intervention.

Results from Schöll and Binder [29] showed that experts interviewed weighed the human capital highest and the health capital the lowest, whereas farmers had the opposite weighting scheme. This implies that if experts invest in increasing farmers' human capital, which was weighted lowest by farmers, their intervention might not lead to the expected result as farmers weigh health above human capital. Thus farmers were not interested in increasing their human capital but were concerned about their health care system instead. This finding is confirmed by the fact that in the study most of the educational programs (also health related ones) have had no or little effect.

3.2.3. Part II: Interaction and Dynamics between the Individual Capitals

The goal of this part of the interview is, first, to obtain a pooled experts' influence diagram or a relational model of the interactions among the different individual capitals within farmers' livelihood. Second, it is to gain first insight into the dynamics of the livelihood system with respect to the specific risk analyzed. The model obtained is then used for designing farmers' interviews.

Furthermore, in the interview, farmers and experts have to explain the types of dynamics they consider relevant to the particular risk analyzed. That is, differences between experts and farmers will point to differences in priorities, risk balancing and views on trade-offs among the capitals. The dynamic perspective also provides insights into the origin of misunderstandings and miscommunications, as a similar interpretation of the past and a similar view of potential future development are key aspects in designing strategies in which experts and farmers' strive towards the same goals [66,67].

Interview

The expert interview. We suggest that experts be given a figure depicting the different individual capitals (Figure 2). Then, in the form of guided interviews they are questioned, always starting from a different type of capital,

- to analyze what a change in one capital state would have on the other capitals states, considering the specific risk analyzed;
- to depict the effects of one capital on another capitals with arrows in the diagram;
- to explain the depicted changes utilizing the elements they used to define the capitals.

For each new set of questions (and capital from which the questions start) a new diagram should be used. This approach structures experts' knowledge from the beginning of the interview (Table 9). We expect that, depending on expertise, the expert will depict and explain the interactions between the capitals with a different degree of detail.

The farmer interview. As a preparatory step for the farmers' interview, one "expert diagram" should be derived from the influence diagrams of all experts depicting both the general characteristics of system most of the experts mentioned and the detailed subsystems for which the different expertise provided specific inputs. From this, open-ended questions for the farmers' interviews should be designed, focusing on specific types of interactions among the capitals, always related to the risk

analyzed. The questions have to be asked in random order and have to include the interaction among the capitals as well as their dynamics consisting of sequential capital influences (for an example see Table 10).

Figure 2. The four capitals (left). Experts have to depict the interaction among these capitals with arrows showing the type and direction of the interaction (right).

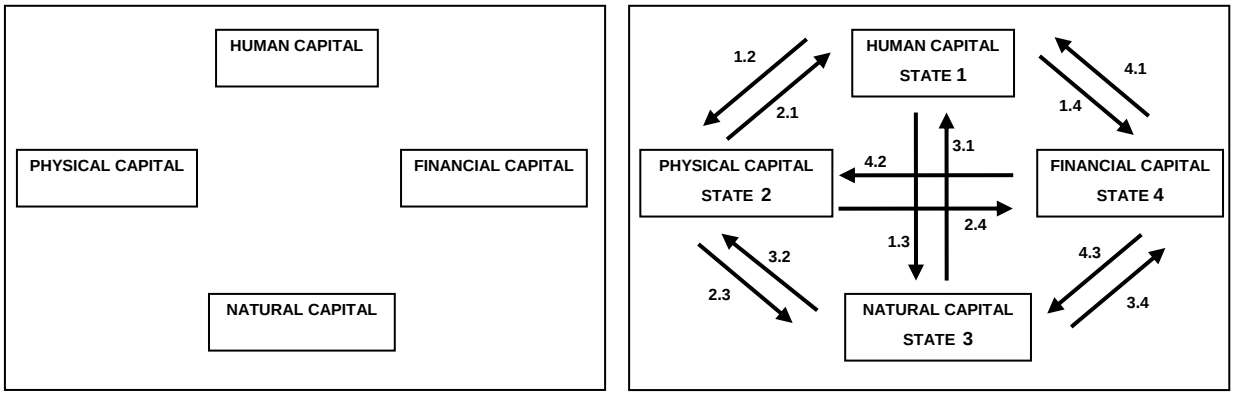


Table 9. Examples of questions posed in Part II of the expert interview.

Part of the interview	**Examples of questions**
System dynamics	Please comment on farmers' livelihood system considering the interaction among the capitals. To what extent and how does farmers *risk management* influence their capital states and respective elements? How does the level of capital state (e.g., high or low wealth, education) influence farmers' perception and decision-making with respect to *risk*?
Influence diagram	Assume that, e.g., farmers' financial capital increases. How will this change affect the other capitals? Please illustrate your statements within this figure. (Figure 2) For example: Increase of human capital→ safer use of pesticides → increase in health→higher labour capacity→ improved livestock → increased profits → higher financial capital → can buy less toxic, more effective pesticides

Analysis

The expert interview. In order to obtain a common experts' system dynamic model, all resulting experts' graphs have to be combined into one single graph. The experts' graphs and their comments are analyzed separately considering two system dynamic aspects: (1) capital state S (*i.e.*, S3 = natural capital state) and (2) capital effect, *i.e.*, effect of one capital on the others (e.g., 1.3 = effect of human on natural capital) (Figure 2 right). Multiple mentioning is summarized; deviations of experts' statements are noted and considered in the interpretation.

Table 10. Examples of questions posed in Part II of the farmer interview.

Capital group	Examples of questions
Human	Did your parents also cultivate potatoes? What other crops did they cultivate? Have the cultivation techniques changed with respect to the ones your parents used? If yes, how?
Human	How did you learn to confront the pests (with pesticides, types of pesticides, biologic crop protection)?
Human	What do you do if you feel sick? (e.g., nausea after applying pesticides)
Physical	What kind of agricultural machineries are you using via a common village organisation?
Natural	How do you judge the quality of your soil? Has it changed since you cultivate potatoes/ carrots?
Natural	What effect do you think have pesticides on plants? …on the soil? …on natural abundance in the fields (biodiversity)? … water?...your health?
Financial	What is the current price of potatoes/carrots? What do the prices depend on?
Financial	What would you do if you had more/less money?

The farmer interview. The summarized statements of the experts' interviews are used to develop the 10 open-ended questions which farmers are asked. Each question targets either specific capital states (1, 2, *etc.* (Figure 2)) and/or capital effects (1.2, 2.4, 3.1 *etc.* (Figure 2)). Farmers' answers are summarized with respect to the targeted aspects, by counting how many farmers' gave the same or a similar statement.

Results and Interpretation. At the end of the analysis for each capital-state and each capital-effect, the statements of experts and farmers are compared applying the qualitative interpretative approach [2]. The effect statements are then analyzed and interpreted to identify the person's risk-related perception of the mentioned effect. For doing so, each statement is rated on a four-level-perception scale measuring the significance of the statement in terms of risk perception, where:

Score 0: no effect perceived
Score 1: effect perceived
Score 2: effect perceived and explained
Score 3: effect perceived, explained and stated to be risk related

All experts' and all farmers' statements scorings are summarized in an expert and a farmer impact matrix (Table 11) to obtain a comparable overview of the scoring.

For example (* in Table 11), in the case of pesticide risks in Colombia, experts did not mention any effect of natural on human capital (0), while farmers attributed this relationship a value of 3, as they stated to learn from their observations of nature (a perception score of 3). Farmers answered the question "What effect do you think pesticides have on plants?" with "when dosage of pesticides is high, the growth and the strength of the plant is affected" and "when pesticides are overdosed, burning of leaves is observed". When asked how they derived these interactions, farmers commented that experts never taught them about the effect of e.g., overdose but they had observed it and thus learned this

interaction by experience. For farmers learning by observations from effects perceived in nature means, that nature had taught them these effects.

Table 11. Theoretical example of an impact matrix of experts *vs*. farmers' risk perception. * = example explained in the text (adapted from Schoell and Binder [29]).

↴	**Human Capital** (E/F)	**Physical Capital** (E/F)	**Natural Capital** (E/F)	**Financial Capital** (E/F)
Human Capital		2/1	3/3	0/0
Physical Capital	1/0		0/1	0/2
Natural Capital	0/3*	2/0		1/1
Financial Capital	3/2	0/3	1/1	

This example shows that differences in the perception of how the capitals are interrelated and how risks to one specific capital might affect the dynamics of the system indicate sources for misunderstandings between experts and farmers. Another example from our application in Colombia showed that experts believe that if farmers had more money they would invest in improving their pesticide management leading to a reduction of health risks, but farmers, in contrast, considered they were sufficiently healthy and would rather invest in producing a different product. That is strategies designed by experts to, e.g., increasing farmers' income for improving their health might not lead to the desired goal.

3.2.4. Part III: Social Capital (Agent Network)

The goal of this part is to identify the social networks farmers are involved in. Of particular interest is not only to whom farmers are connected, but to what degree they feel that different agents are close to them and might influence their decision-making.

We suggest combining the following approaches in the interview (see also Binder [54]): Snowball principle to identify the relevant (direct and indirect) agents [68], and relation mapping through functional and production-consumption interactions [69,70].

Interview

The expert interview. Experts are first asked to name all the agents they consider relevant for the farmers. Then they are requested to illustrate the agent network in a diagram. Thereby the farmer should be placed in the center and the connections to the other agents should be recorded with lines depicting the distance of the farmers to the named agents. Experts are solicited to consider both direct and indirect interactions of the agents with the farmers.

The farmer interview. In a preparatory step, the agents named by the experts are again be categorized and photographs of agents related to the region taken. As in Part I, farmers are first asked to name the agent on the photograph. Then they are requested to build their own agent network by

placing the photographs closer or further away from themselves with respect to their importance for their livelihood and to the specific intervention or risk studied (Table 12). Photographs of the agent models as developed by farmers should be taken and the relative distance between agents, *i.e.*, between the farmer and the different agents should be measured and included in the analysis (Figure 3).

Table 12. Examples of questions posed in part III of the farmer interview.

Topic	Examples of questions
Agents network	Who is the agent depicted in this photograph?
Agents network influence diagram	If you were here, place the agents recognized on the cards around you by considering how close you feel to every agent compared to the others
	(1) If you feel that Agent 1 and Agent 2 are equally close to you, then place both cards around you
	(2) If you feel closer to Agent 1 than Agent 2, place the card of Agent 1 closer to you than the card of Agent 2
	(3) If you feel Agent 2 is leading you to Agent 1 then place Agent 2's card between you and Agent 1
	(4) If you look at the final placement of the cards given to you, are any agents missing?

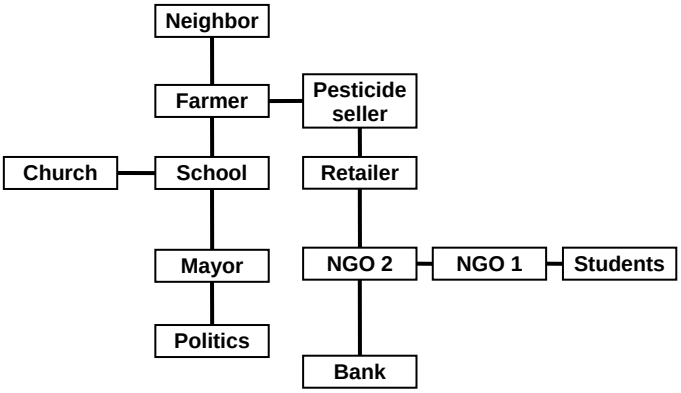
You

Agent 1 You Agent 2

Agent 1 You Agent 2

You Agent 2 Agent 1

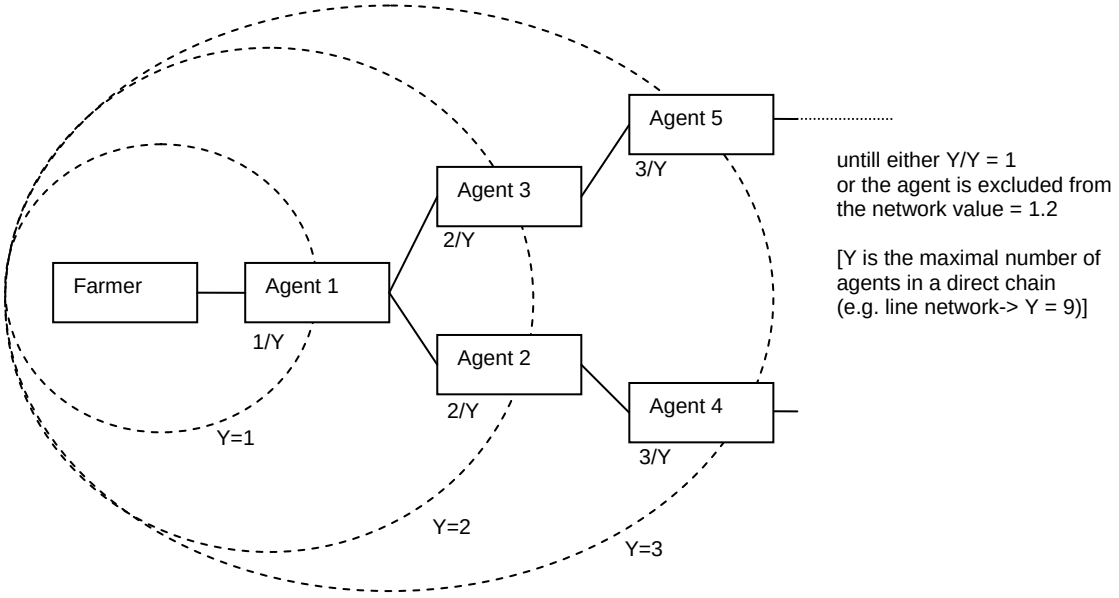
Figure 3. Example: agent network constructed by a farmer and its graphical representation (adapted from Mosimann [61]).



Analysis

The expert interview. The agent networks of the experts are summarized and the most frequently named agents by all experts selected. Subsequently an expert agent network is constructed and validated with experts. Finally the obtained network is represented as a line network. The position of the agent on that network is found by calculating the distance of the agents to the farmers as shown in Figure 4.

Figure 4. Example: agent network analysis.



The farmer interview. In analogy, to analyze the farmers' agent networks the elicited agent network structures are analyzed and are represented in a line-network as shown in Figure 3. Additional named agents by the farmers are noted down and have to be considered when interpreting the analyzed data.

Results and interpretation. The agent network analysis provides first information about how close experts and farmers see specific agents to be related to farmers. Farmers' explanations regarding the perceived closeness of agents within their network might pinpoint issues such as trust. Differences between experts and farmers might additionally elucidate why interventions by specific agents might not be as successful as expected.

Second, the structure of the elicited networks (e.g., a straight line *versus* a spider type network) can be analyzed and compared. The type of structure characterizes the embeddedness of the farmer in his/her social surroundings and provides first insights into their access to other capitals through the social capital available. Furthermore, for experts, the knowledge of farmers' views on agents' networks might be of relevance when looking for partners to implement change programs.

5. Discussion

This paper presents a method, the Structured Mental Model Approach (SMMA), for analyzing diverging system perspectives between experts and farmers regarding the perception of farmers'

livelihood, related risks and potential utility of interventions in the rural areas of developing countries. Specifically, the SMMA:

(i) structures the interviews to first understand farmers' perception of their livelihood and livelihood risks and potential gains.
(ii) allows for comparing farmers' perceptions to the ones of experts
(iii) supports the analysis of potential sources of misunderstandings, and thus
(iv) supports the development of sound intervention strategies

In the following specific gains from applying the SMMA are highlighted, followed by the need for further research.

5.1. Insights Gained with the SMMA

5.1.1. Understanding Farmers' Local Knowledge and Individual Motives and Values

The SMMA supports the understanding of farmers local knowledge, their motives and values as claimed for by de Svenson [22], Walters *et al.* [71], and Haan and Zoomers [16], as follows. First, the analysis of farmers' mental models makes the underlying logical thinking structure (local knowledge) explicit, supporting the understanding of the role of livelihood capitals for farmers' decision-making. Second, the comparison to experts' mental models enables for pinpointing specific differences between experts and farmers in the definition, priorization, and dynamics among the livelihood capitals and supports thus the development of appropriate communication techniques.

The utility of the SMMA becomes evident when looking at the results of capital definition and weighting in the case of Vereda la Hoya, Colombia [29]. Example 1 (Table 13) shows the case where the element definition and the weighting were different between experts and farmers. In this case, the expected farmers' decision by experts is likely to be the same than what farmers would do, but the underlying logic of experts and farmers is completely different. Example 2 (Table 14) illustrates the case in which the weighting of the capitals is the same but the definition of the capitals is not. In this case even if farmers and experts would apparently talk about the same capital weighting (financial over natural), if experts would design measures to improve the natural capital, they might instead be fostering the financial one.

These results suggest that for designing interventions and communication campaigns three issues have to be considered: First, how farmers define the capitals, second, how they rank them, and third, how they perceive the interaction among them.

Table 13. Example 1 for Vereda la Hoya, where the same expected action by experts and farmers is due to different element definition and weighting.

	Technical assistance placed in	**Ranking**	**Potential outcome**
Farmer	Financial capital	Financial > Human	Same expected decision but different capital definition and weighting
Expert	Human capital	Human > Financial	

Table 14. Example for Vereda la Hoya, where apparently same capital weighting leads to different expected actions if the capital definition is not elicited.

	Pesticide management placed in	**Ranking**	**Potential outcome**
Farmer	Financial capital	Financial > Natural	Apparently same capital weighting leads to different expected decisions if the capital definition is not elicited.
Expert	Natural capital	Financial > Natural	

5.1.2. Accounting for the Role of Social Capital and Access to Individual Capitals

In SMMA, to understand the social network farmers are embedded in, their agent network is analyzed. The agent network describes the closeness of different agents to the farmers and allows for analyzing the access of farmers to e.g., human capital (e.g., technical assistance), or financial capital (e.g., closeness to and experiences with banking or credit institutions). This insights are essential for designing intervention strategies to improve the sustainability of farmers' livelihood. For example in the case study of pesticide management in Vereda la Hoya, we found that the perceived closeness to local markets affects the decision on how farmers produce potatoes (e.g., input use) which in turn affects the financial capital. The obtained results suggest that a separate analysis of the social capital, specifically, farmers network, might give significant insights into the role and influence of different experts on farmers from which the key agents can be selected and cooperated with.

5.1.3. Systemic Embedding of the Intervention Planned or Specific Risk to be Studied

Interventions or risks farmers are exposed to, have to be seen within farmers' livelihood, as each intervention or each risk assessed is always in relation to other parts of farmers' livelihood or risks [45]. With the SMMA we provide an approach to investigate the trade-offs between the different livelihood capitals as seen from an expert and a farmer perspective.

In the case of pesticide management in Colombia, we found that improving the communication and education of a specific e.g., health risk, it would not be sufficient to improve the health situation of farmers, as farmers do not see any connection between knowledge and health related risks. However, looking at the whole picture suggests that the best way to support farmers in improving their health situation is to consider their faith and the influence of their faith on decisions concerning health protection [29].

5.1.4. Identifying Potential Origins of Misunderstandings

The results from the SMMA provide a basis for identifying origins of misunderstandings between experts and farmers. In the first step, the capital definition, differences in the definition of capitals already provide preliminary insights into potential sources of misunderstanding (Table 15). Having the same definition and understanding of a term is the basis for successful communication. When weighting the capitals, the priorities of farmers and experts are clearly defined. Communication based

on a different type of weighting is likely to fail, since the common denominator is missing and messages may easily be misinterpreted. The differences in capital interaction and system dynamics, elicited in the second step, show the interpretation of past incidences and allow assumptions on to future behavior. In the third step, the farmers' agent network, aspects such as trust and confidence impact on how farmers see their closeness to different agents. From this step, it is possible to deduce which agent is likely to be effective with his/her interventions and which not.

5.2. Policy Relevance

We consider that the results that can be obtained with the SMMA provide a sound basis for the design of interventions, communication and educational programs. Risk communication is more effective if it is related to the whole system affecting the subjects' lives [45]. In the SMMA this is assured through the inclusion of the system dynamics of the different capitals of farmers' livelihood in the mental models. The mental models obtained, thus, on the one hand, allow for a thorough scientific analysis of the differences between experts and farmers, and on the other, open the door for an effective risk communication and development of educational programs [2]. The embedding of the mental models into the context of farmers' livelihood, furthermore, allows for the design of holistic policies which consider the views of farmers on their own livelihood, as well as the perception of their own problems. Thus, the way in which farmers "balance" the risks of the different capitals and see the trade-offs between the different capitals can be made explicit.

In addition, experts' understanding of the embedding of e.g., pesticide risks in farmers' livelihood allows them to develop strategies and options for change that consider farmers' priorities and viewpoints. This allows for developing strategies in expert-farmer teams.

Considering the different literacy levels in less developed countries

The SMMA was designed to include different levels of systemic abstraction as discussed by Johnson-Laird [32]. We used monadic, set-theoretic and relational models. In a first trial in Vereda la Hoya, Colombia [29], experts had no problem using and relating to these different types of models. For farmers the case was slightly different. Farmers related well to the monadic models, *i.e.*, they recognized the photographs, could define them properly, and were able to relate them to an abstract concept. This was even true for photographs depicting different parts of the health care system in Colombia [29]. This suggests that, in the context of Latin America, photographs are a good way of testing the ability of farmers to build monadic models. In other cultural backgrounds, alternatively painting on a sandy soil [21] or weighting with stones [72] might be considered.

Farmers were also able to conceptualize a set-theoretic model. Our first experiences suggest that the consistency of farmers with experts' allocation (of elements to capitals) decreased with decreasing level of human capital. Finally, the building of relational models was handled well by farmers suggesting that, first, the approach to build the relational model by using open-ended questions about relations described by experts is adequate in this cultural setting. Second, farmers can easily relate to a systemic context also considering interactions [28]. This insight is relevant for developing measures to reduce a specific risk, implying that educational programs should always encompass both information on the whole system and the interrelationship to the specific risk to be reduced.

5.3. Critical Issues, Validation and Need for Further Research

5.3.1. Critical Issues

A few caveats to this approach should be noted. First, a theory driven approach might bias the results obtained, as people are guided in their thinking with respect to a specific framework. That is, even though at each step experts and farmers are asked if important aspects are missing, relevant system features might not be included in the mental models. In the Colombian case this was the case, for example, for gender issues.

Second, experts' mental models are taken as the basis for analyzing farmers' mental models. That is, one underlying assumption is that the expert models are the "correct" or "objective" ones. This is one issue that has also been criticized in the MMA [6,45,46,47]. This might lead to a neglect of specific topics or issues. In our approach this issue is slightly minimized through a specific theoretical background. When applying the SMMA for analysis of the future, we reversed the order of the questioning. This led to higher focus on farmers' viewpoints concerning farmers' future [35].

Third, an issue when such a complex system is analyzed is the consistency of the expert model. In both case studies we chose experts from different fields, to assure a proper representation of the system. In the Colombian case, where Colombian experts were chosen, expert mental models merged nicely to one expert model [29]. In the Nicaraguan case we included also experts from Switzerland. Here it was much more difficult to merge the different models [61]. In future research, the robustness of the expert models in dependency of the degree of specialization should be studied.

Fourth, the time required for performing an SMMA in the field is approximately two weeks; farmers interviews lasting two hours each. This implies that earlier contact with the farmers is required to build trust. In the Colombian case, the University we have been collaborating with had been performing projects (mostly schooling projects) in the study area during the last 5 years building trust with the population. One of the main contact persons accompanied the researcher in her field visits and performed part of the interviews. Thus, farmers were comfortable with and trusted the research team.

Fifth, if the approach is to be applied to another research area, a sound theoretical and conceptual background, as in our case, the livelihood approach, is required. This implies that some research on the general system characteristics should already have been carried out to be able to build on existing systemic knowledge.

5.3.2. Validation

In contrast to environmental process models, mental models are rather difficult to validate. In the case of the Colombian case study, an anthropological study was carried out in the same study area, also analyzing farmers' perception and behaviour regarding pesticide management [73]. The specific systemic information obtained, and also elicited with the SMMA, e.g., perception of farmers' livelihood, risks, was the same with both approaches. That is, the information obtained with the SMMA on farmers' perceptions is adequate. As mentioned above, in the ethnological study additional issues were looked into as gender aspects, labour distribution within the household. This gives additional insights about the system, which were not aimed for in the SMMA.

5.3.3. Further Research

The SMMA opens the room for further research in several directions:

First the link between mental models and current behaviour could be analyzed. The next envisioned research step is to derive with the SMMA the mental models and with a survey the current behaviour of two farmer groups within one region (one control group). Based on the analysis, interventions for improving farmers' livelihood are designed. After two years the analysis is repeated to obtain longitudinal data on the mental models and farmers behaviour. Optimally this analysis should be repeated periodically. We performed a pre-test of such a study, comparing intervened and non-intervened farmers with similar characteristics in neighbouring regions in both case studies. The preliminary results suggest that the type and potential effectiveness of intervention is reflected in the change/non-change of farmers' mental models. In the Colombian case we found differences in the mental models between the intervened and non-intervened farmers, while in the Nicaraguan case these differences were minimal. We aim at deepening this analysis to provide recommendation for successful interventions.

Second, factors affecting the mental models could be studied. Of particular interest could be to link the different personality factors [74] for an excellent review) with the resulting mental models of farmers. These factors might affect the way farmers think. This becomes even more relevant when studying the mental models of the future [35]. Additionally, one could relate farmers' livelihood capitals to the way they perceive their capitals.

Third, similarly one could think of analyzing farmers' perceived gains of potential strategies to minimize livelihood risks, such as diversification. That is, one would analyze the "objective" gains of diversification measured by experts and the way experts conceive the system dynamics to get there. An interesting question would be to inquire the way farmers perceive the same strategy and whether the system dynamics farmers perceive are in agreement with the one of experts. If it were not the case, one could envision designing educational programs based on that knowledge in order to engage into a mutual learning process regarding the system and its dynamics.

Finally, the presented methodology has been developed and tested in a Latin American context [29,61]. We consider that further research is needed when adapting the methodology to other cultural contexts for example India or China. In particular the design of farmer interview, e.g., with photographs or pictograms will have to be developed.

6. Concluding Remarks

This paper presented the SMMA as a tool for understanding specific farmers' risks in relation to their livelihood and to distinguish between the risk perception of farmers and experts in developing countries. It provides a system based structured procedure which allow for specifically (i) analyzing the weighting of risks within farmers livelihood and their interrelationship, (ii) identifying the trade-offs farmers face; and (iii) understanding the thinking behind the way farmers balance their risks.

Furthermore, the SMMA presents a basis for identifying potential origins of misunderstandings between experts and farmers (Table 15).

Table 15. Overview of data analysis.

Interview part	Target capital	Aspect analyzed	Analysis and result presentation	Risk aspect considered
Part I	Individual capitals	• Definition of capitals	• Matrix showing elements used for capital definition	• Level of baseline understanding
		• Relative importance of capitals	• Ranking table	• Trade-offs between livelihood capitals
Part II	Individual capitals	• System dynamics	• Separate "state" and "effect" statements • Livelihood and risk perception matrix	• Origins of difference in risk perception
Part III	Social capital	• Definition of agents	• Agents named by experts • Recognized and complemented agents by farmers	• Active agents working in the region and their perceived relevance
		• Agent network	• Distance in network • Structure of network	• Agents role in interventions

In the first step, the capital definition, differences in the definition of capitals already provide preliminary insights into potential sources of misunderstanding. Having the same definition and understanding of a term is the basis for successful communication. When weighting the capitals, the priorities of farmers and experts are clearly defined. Communication based on a different type of weighting is likely to fail, since the common denominator is missing and messages may easily be misinterpreted. In the second step, the analysis of the capital interaction and system dynamics, the potentially largest differences are to be found. These differences may have their roots in the different definition and weighting of the capitals. They will additionally show the interpretation of past incidences and allow extrapolation to future risk-averse or risk-taking behavior. In the third step, we analyze the farmers' agent network. Here aspects such as trust and confidence in the agents involved may affect how farmers see their closeness to themselves. From this step, it is possible to deduce which agent is likely to be effective with his/her interventions and which not. Differences between experts and farmers and, moreover, the explanations of such, will show where the misunderstandings are and how agents have to change to potentially overcome them.

First empirical applications of the SMMA have shown that the method is applicable to different issues within rural livelihood research to identify the differences in mental models between experts and farmers. Based on these results, on the one hand, communication and schooling strategies to improve farmers' livelihood can be set up. On the other hand, the results can be extrapolated applying a representative survey and utilized for developing quantitative behavioral and dynamic simulation models to assess strategies and future perspectives of farmers and experts.

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Paper 2

System Perspectives of Experts and Farmers Regarding the Role of Livelihood Assets in Risk Perception: Results from the Structured Mental Model Approach

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System Perspectives of Experts and Farmers Regarding the Role of Livelihood Assets in Risk Perception: Results from the Structured Mental Model Approach

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Pesticide application is increasing and despite extensive educational programs farmers continue to take high health and environmental risks when applying pesticides.

The structured mental model approach (SMMA) is a new method for risk perception analysis. It embeds farmers' risk perception into their livelihood system in the elaboration of a mental model (MM). Results from its first application are presented here. The study region is Vereda la Hoya (Colombia), an area characterized by subsistence farming, high use of pesticides, and a high incidence of health problems. Our hypothesis was that subsistence farmers were constrained by economic, environmental, and sociocultural factors, which consequently should influence their mental models.

Thirteen experts and 10 farmers were interviewed and their MMs of the extended pesticide system elicited. The interviews were open-ended with the questions structured in three parts: (i) definition and ranking of types of capital with respect to their importance for the sustainability of farmers' livelihood; (ii) understanding the system and its dynamics; and (iii) importance of the agents in the farmers' agent network. Following this structure, each part of the interview was analyzed qualitatively and statistically. Our analyses showed that the mental models of farmers and experts differed significantly from each other.

By applying the SMMA, we were also able to identify reasons for the divergence of experts' and farmers' MMs. Of major importance are the following factors: (i) culture and tradition; (ii) trust in the source of information; and (iii) feedback on knowledge.

KEY WORDS: Culture; farmers; mental models; pesticides; trust

1. INTRODUCTION

Pesticide misuse and its related health and environmental problems in less developed countries is a widely discussed issue. Since the green revolution, the use of chemical inputs per hectare, that is, fertilizers and pesticides, has been substantially increasing.[1,2] The effect on productivity has been considerable: it is estimated that if pesticides are properly applied, crop losses can be reduced by about 40%.[3]

However, pesticides have not only had positive effects. Misuse of pesticides can lead to severe environmental and human health effects.[4,5] Whereas in developed countries the environmental impacts are of major concern (fish toxicity, soil damage), in developing countries increased mortality and morbidity of humans due to exposure to pesticides are experts' main issues of concern.[2] For example, Richardson[3] found that the misuse of pesticides

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causes a higher incidence of child cancer. Pesticide producers and appliers suffer more often than the local population from peripheral neuritis (>40%), psychiatric manifestations (>40%), electroencephalographic (EEG) changes (>25%), and hepatorenal dysfunction (>80%).[6] Additionally, it is assumed that there may also be indirect and long-term impacts of pesticide misuse, such as lower life expectancy and decreasing soil productivity, which would affect farmers' livelihood persistently.

Misuse of pesticides in developing countries relates to (i) lack of adequate protection during the mixture and application procedure; (ii) inadequate storage facilities; (iii) a higher amount and frequency of application than in developed countries; and (iv) the application of stronger products often forbidden in developed countries.[1,2,7]

Studies have mostly focused on understanding which variables might influence pesticide application behavior. For example, land ownership and access to credit increase pesticide use,[8] whereas increased education and wealth of farmers seem to result in reduced pesticide use or even the adoption of integrated pest management practices.[9] In contrast, Swinton[10] found that wealthier farmers in Latin America, even though they had the financial capacity to use pesticides more appropriately (less toxic pesticides, better equipment), did not do so. They hypothesized that this was because farmers lacked incentives to perform good pesticide stewardship. Abdulai and Binder[11] showed for the case of Nicaragua that farmers' decisions on the amount of pesticides applied also significantly depend on earlier managerial decisions made, such as burning or not burning the crop residues on the field. This finding is important as it shows that farmers do include their system knowledge when making decisions. Ryder[12] also confirmed this finding by showing that farmers in the Dominican Republic had an unsophisticated soil taxonomy based on their empirical knowledge of site characteristics that could be related to a scientific site suitability rating.

Because of the above-mentioned health and environmental effects of pesticide misuse, the international community and the chemical companies have made substantial investments and developed educational programs to reduce the misuse of pesticides; however, they have not had the expected success. One of the reasons is that to a large extent farmers' perception of risks related to pesticide use has neither been investigated, nor included in the development of educational programs. Additionally, pesticide misuse has never been put in relation to other types of risks affecting farmers' livelihood. Even though several authors have emphasized that risk perception or risk strategies have to be studied in relation to farmer livelihood and the system knowledge of farmers, the focus is still mostly on specific risks, such as environmental risks, for example, soil erosion.[2–4] Thus, we consider that farmers' risk perception[1] should be investigated and farmers' perception of pesticide risk compared to the perception of the other risks they confront.

When studying farmers' risk perception one has to analyze, first, which aspects constitute a specific risk perception, and, second, which factors influence risk perception. Regarding the first, farmers' risk perception consists of two important, interrelated aspects: first, farmers' reasoning about the risks of pesticide application per se; and second, farmers' balancing of pesticide risks against other livelihood risks, such as financial and natural risks, in their everyday life. Second, farmers' risk perception is influenced by (1) the social structure they are embedded in, including culture, traditions, belief systems, and tacit and explicit norms;[13–15] (2) the assets and the capabilities they have access to;[16–18] and (3) the social network they are embedded in.[19–22]

To account for the aspects of risk perception and the influences on farmers' risk perception Binder and Schöll developed the structural mental model approach (SMMA).[16] SMMA[16] combines the mental models approach (MMA)[23–25] with the livelihood approach.[26] It allows the inclusion of farmers' livelihood in the analysis of their mental models (MM),[27,28] discriminating among different values of thinking and conceptualizing.

In this article, the first empirical application of the SMMA is presented for the case of pesticide management in Vereda la Hoya, Boyaca, Colombia. By doing so, we aim at:

(1) analyzing farmers' and experts' discrepant MMs of their risk perception of pesticide management within the livelihood context of farmers;
(2) exploring the causes of discrepancies between MMs of experts and farmers; and
(3) analyzing inappropriate pesticide management with respect to risk communication.

[1]Definition of perception: **Perception** is the process of acquiring, interpreting, selecting, and organizing information.[23]

The article is structured as follows. We first describe the study area. We then describe the interview subjects and the specific application of SMMA to pesticide use risks. In Section 4, we present the outcome of SMMA application, structured into the three characteristic SMMA parts. Ultimately, we summarize and discuss the results in terms of further implications, limitations of the method, relevance for policy making, and further research.

2. STUDY AREA

The selected study area, Vereda la Hoya, is located in the rural part of Tunja, the capital of the Departamento de Boyacá (Colombia). La Hoya ranges from 2,700 to 3,250 masl over an area of 8 km^2 (840 ha), has an average temperature of 12°C, and a population of about 747 inhabitants (130 families). The main source of income is farming. Farmers cultivate minifundios, that is, their property has an average size of 6.6 ha.[29,30] The land use pattern is crop production 40%, animal husbandry 25%, fallow land 33%, and forest 2%. The main agricultural products grown in la Hoya are: potato 27%, vetch (carrots) 23%, corn 18%, horse bean 18%, wheat 9%, and onion 5%. Usually, the land is cultivated in two cycles a year (September to February and March to August), which permits two harvesting seasons, February and August. The typical rotation consists of 2–3 cycles of potato, 1–2 cycles of carrots, and 2–4 cycles of fallow land.

In Colombia, agriculture accounts for 21% of the GNP and 40% of the labor force.[31,32] It has been estimated that the amount of pesticides used per year is about 40,000 tons.[33]

Potato production in la Hoya is vulnerable to three major pests, the soil-dwelling larvae of the Andean weevil (*Premnotrypes vorax*, "Gusano blanco"), the late blight fungus (*Phytophthora infestans*, "Gota"), and Guatemalan potato moth (*Tecia solanivora*, "Polilla Guatemaleca"). For the control of these pests both farmers and agricultural scientists consider the use of both insecticides and fungicides necessary. Up to 12 applications of each are required.[34] In this study region, the predominant pesticide used for potato production is carbofuran (an insecticide and nematicide; potential health effect: respiratory system failure) followed by mancozeb (a fungicide; potential health effect: sensitization rashes) and methamidophos (an insecticide; potential health effect: delayed neurological problems).[29,35–39]

3. METHODS

3.1. The Subjects

To collect data for the SMMA, interviews were conducted with 13 experts and 10 local farmers.

3.1.1. Experts

The sample of 13 experts consisted of 5 females and 8 males, half of them were between 30 and 40 years old while the rest were between 40 and 50. The expert group included a mixture of professionals from different scientific fields of the system being analyzed (Binder & Schöll, submitted): pesticide producers: that is, pesticide sellers, representatives from governmental technical assistance institutes and health ministries, a toxicologist, a medical doctor, economists, and an agronomist. Two of them had been locally involved, five had a regional perspective, and six worked at a national level (see Table I).

The 10 experts differed in the following criteria: (i) knowledge of the local, regional, or national system; (ii) expertise in different aspects of the livelihood system; (iii) hypothesized position within farmers' agent network.

3.1.2. Farmers

The 10 farmers interviewed were all male and between 24 and 40 years old. From earlier studies,[34,40] we know that men are the key decision-makers concerning pesticide use and, moreover, the ones applying pesticides in the field. Therefore, we performed the interviews only with men. The sample was selected by purposeful sampling, including individuals from different parts of the study region, who differed in the levels of their livelihood capitals (human, natural, financial, and social) (see Table II).

During the farmers' interview, we observed a drop-off of new concepts after 4–5 farmers. In agreement with Maharik,[41] we completed the farmers' sample with 10 participants.

3.2. The SMMA Method

The SMMA developed in Binder and Schöll[16] was applied in this research following the three analytical steps of the method (Table III). In contrast to other livelihood analyses, the application of the SMMA in the context of pesticide management

Table I. Overview of Experts Interviewed

Age (Years)	Gender	Education	Profession	Working Entity
30–40	f	Agricultural engineer	Pesticide seller	Regional level
40–50	m	Agronomist	Pesticide seller	National level
30–40	f	Toxicologist	Laboratory technician	National Health Institute[a]
40–50	m	Chemist	Laboratory technician	National Health Institute[a]
40–50	m	Economist	Professor	University[b]
40–50	m	Secretary (with toxicology background)	Public servant	Ministry of Health[c]
30–40	f	Microbiologist	Laboratory technician	National Health Institute[a]
30–40	f	Agronomist	Private technical assistance	Independent regional cooperation of Boyaca[d]
30–40	m	Agricultural engineer	Professor	University[e]
30–40	m	Agricultural engineer	Public technical assistance	Municipal entity of agricultural technical assistance[f]
40–50	f	Medical doctor	Pesticide stewardship	Syngenta
40–50	m	Economist	Professor	University[e]
40–50	m	Medical doctor	Medical doctor	Hospital St. Catalina

[a]Instituto Nacional de Salud, INS.
[b]Universidad de los Andes, Bogota.
[c]Ministerio de Proteccion Social, MPS.
[d]Corporación Autónoma Regional, CORPOBOYACA.
[e]UNIBOYACA, Tunja.
[f]Unidad Municipal de Asistencia Técnica Agropecuaria, UMATA.

Table II. Overview of Capital States of the Interviewed Farmers

Capital[a]	High (State)	Low (State)
Human	Education: 8 years of primary school	Education: no formal education
Health	No specification[b]	No specification[b]
Natural	Soil: fertile soils	Soil: less fertile soils
	Inclination: low	Inclination: high
	Forest: owns land with natural forest	Forest: does not own any land with natural forest
Financial	10 ha of own land	Landless farm worker
Social	Social status: community leader	Social status: isolated member of community

[a]Covering the livelihood of farmers, see Section 3 for definition.
[b]As there was no information about health effects related to inappropriate pesticide use, the farmers could not be selected with respect to their differences in health capital state.

Table III. The Structured Mental Model Approach (SMMA)

	Experts' Interview	Farmers' Interview	Livelihood Aspects Considered	Risk Aspects Considered
Part I	• Listing of relevant capital group elements • Weighting of the capitals	• Grouping of the elements in the four capitals groups • Weighting of the capitals	• Definition of human, health, natural, and financial capital	• Origin of differences in risk knowledge • Risk-balancing (tradeoffs), difference in importance
Part II	• Showing how the elements are related	• Answering open-ended questions on the relations found by the experts	• Explanation of dynamics among human, health, natural, and financial capital	• Origins of difference in risk perception
Part III	• Listing the relevant system agents • Designing an agents network	• Designing an agents network with the agents listed by the experts	• Definition of the social capital • Explanation of relations within the social capital	• Agents and their role in successful interventions

Table IV. Example of Element Consolidation and Photographic Representation

Elements Named by Experts		Consolidated Element		Regional Relation		Photograph
• Hospital • Private clinic • SISBEN (public health insurance)	→	Medical treatment	→	Regional hospital people can and will go to	→	Regional hospital 

requires that health capital is considered as a separate capital to optimally analyze the perceptions concerning health and health risks.

3.3. Analysis

The results of the SMMA were analyzed and structured according to the three steps of the method. In each of the interview parts, answers from the expert interviews were summarized to make a single expert model and the different answers of the farmers were compared to that. This way of proceeding originates from the MMA[24] method.

3.3.1. Analysis Part I

In Part I, experts were asked to name important characteristic elements of the exemplified four capitals: human, health, natural, and financial capital.[16] Afterward, they were asked to rank these capitals in order of importance to farmer livelihood. From the most frequently named elements of the capital definition, pictures were taken in the field and used for the farmer interviews (see example in Table IV). Farmers had to first define the element represented in the picture by explaining what they saw in each picture and second place it in a capital group, explaining their choice. The expert and farmer results were summarized in a table (see Section 4 and Table VIII).

3.3.2. Analysis Part II

In Part II, the system dynamics were analyzed. The experts were asked to draw and discuss a system dynamic graph from a blank system picture (Fig. 1 left). In order to obtain a common experts' system dynamic model, the resulting 13 graphs were combined into a single graph. Each capital was numbered (human = 1, health = 2, natural = 3, and financial = 4).

Expert and farmer system dynamics explanations were summarized by capital in: (a) capital state (e.g., human capital state = S1); (b) capital effect (e.g., effects of human on health capital = 1.2; see Fig. 1, right).

The capital state and effect nomenclature was also used to structure and relate each question of farmers' open-ended interviews to the specific system dynamic aspect (see Table V, rightmost column).

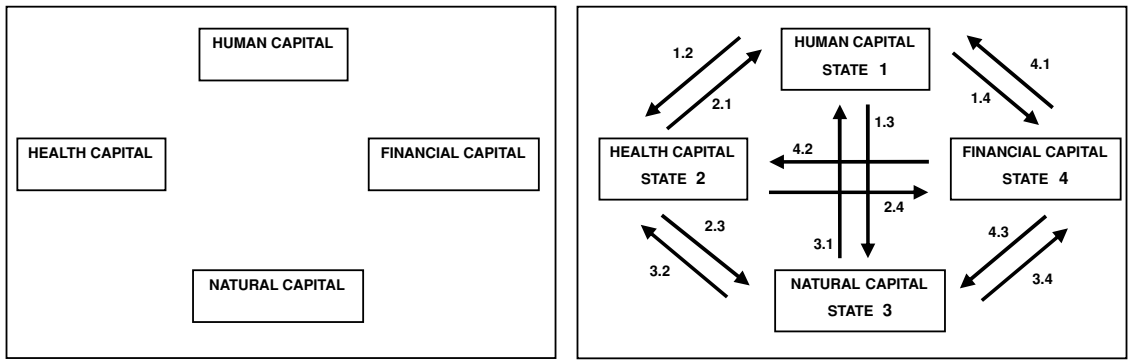

Fig. 1. System overview: Default (left), system dynamics analysis scheme (right).

Table V. Open-Ended Questions Related to System Dynamic Explanations of Experts Posed to Farmers in Part II of the SMMA

Related Capital	Questions	State or System Relation		
Human capital	What happens if the harvest is affected by pests and climatic conditions?	1.3		
	Have you noticed a change of climate over the past years?	S3		
	Who (or whom) do you ask for help when the harvest is affected?	S1	1.3	
	Did your parents also cultivate potatoes?	S1	1.3	
	What other crops did they cultivate?	1.3	1.4	3.1
	How have the cultivation techniques changed with respect to the ones your parents used?	1.3	1.4	3.1
	How did you learn to deal with pests . . .	S1	1.3	3.1
	. . . with pesticides. . .	S1		
	. . . types of pesticides. . .	S1	3.4	
	. . . biologic crop protection?	S1		
	How do you protect yourself when you mix and apply pesticides?	1.2	2.1	
Health capital	What do you do if you feel sick?	1.2	4.2	2.4
	. . . while applying pesticides?	2.1	1.2	
	. . . nausea after applying pesticides?	2.1	1.2	
Natural capital	How do you judge the quality of your soil?	S3	3.1	
	Has it changed since you started to cultivate potatoes/ carrots?	3.1	S3	
	What kind of crop rotation do you carry out?	S1		
	. . . and why?	1.3		
	What pests are you confronted with?	S3	3.1	
	What effect do you think pesticides have on plants . . .	1.3		
	. . . on the soil?	1.3		
	. . . on natural abundance in the fields?	1.3		
	. . . on water?	1.3	3.2	
	. . . on your health?	1.2	3.2	
	. . . on biodiversity?	1.3		
Financial capital	How good is the current price of potatoes and/or carrots?	S4		
	What do the prices depend on?	1.4	3.4	4.3
	What would you do if you had more/less money?	4.3	4.1	4.2

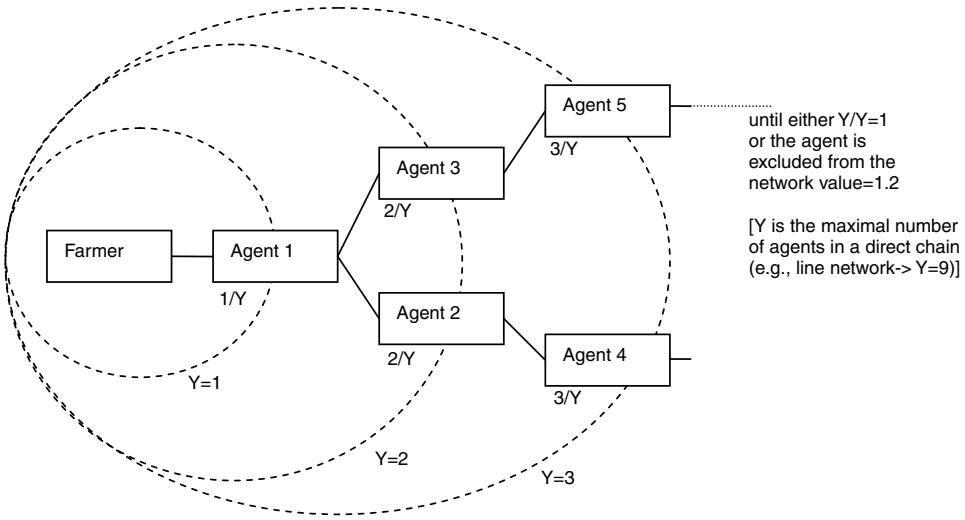

Fig. 2. Agent network analysis.

Table VI. Examples of Photographic Representation of the Selected Agents

Named Agent by Experts		In Field Representation		Photograph
Junta (Famers' Union)	→	Who is a member or even the president of the junta of Vereda la Hoya	→	Junta 

Farmers' questions were asked in random order in each interview.

The questions were asked in random order in each interview. For comparing the experts' and the farmers' statements, we used a qualitative interpretative approach as described by Morgan.[24]

Finally, the effect statements were analyzed regarding what each statement revealed about the person's risk-related perception of the mentioned effect. Each statement was rated on a 4-level perception scale revealing the significance of the statement in terms of risk perception (no effect perceived: score 0; effect perceived: score 1; effect explained: score 2; effect perceived is risk related: score 3). All experts' and all farmers' statements scorings were summarized in an experts and a farmers table to obtain a comparable overview of the statements.

3.3.3. Analysis Part III

In Part III of the interview, the agent networks of experts and farmers were analyzed to account for the social capital of farmers' livelihood. The agent network per se does not provide a direct insight about information concerning pesticide management. It presents a general view about the agents experts and farmers have in mind when providing or inquiring information. The experts were asked to name the relevant agents and to draw an agent network. These agent networks were summarized and the nine most frequently named agents by all experts selected. Again, photographs of these nine agents were taken and used for the farmer interviews (see example in Table VI).

The farmers were asked to place the photographs of the agents nearer or further away from themselves, constructing a personal agent network. The farmers' agent networks were analyzed according to the agents' distance from the farmer as shown in Fig. 2.

4. RESULTS

In this section, the results highlighting the main differences between experts' and farmers' mental models with respect to risk perception of pesticide use are presented. The results are again structured according to the three parts of the SMMA interviews.

4.1. Part I: Definition and Weighting of Farmers' Individual Capitals: The Monadic and Set-Theoretic Model

Table VII shows the differences in capital definition between experts and farmers. Experts and farmers agreed that *culture* and *education* belonged to human capital, that *medical doctors*, *the governmental health system SISBEN*, and *hospital* belonged to health capital, that *environmental contamination* and *forest* affected or belonged to natural capital, and that *income*, *credit*, *market,* and *machinery* belonged to financial capital.

Of particular interest are the differences in the set-theoretic model of the capitals.[2]

4.1.1. Human Capital

Regarding human capital, two major differences were found. First, experts considered that *technical assistance* contributes to building farmers' human capital, whereas farmers allocated technical assistance to financial capital. The reason that 80% of the farmers gave was that they perceived technical assistance to be directly linked to their financial resources. In the region, wealthy farmers are more likely than poorer ones to receive free technical assistance from the state. Additionally, wealthier farmers can afford and do pay for technical assistance, for example, for soil analyses.

[2]Only issues relevant for livelihood and risk perception are discussed. Additional information will be delivered upon request.

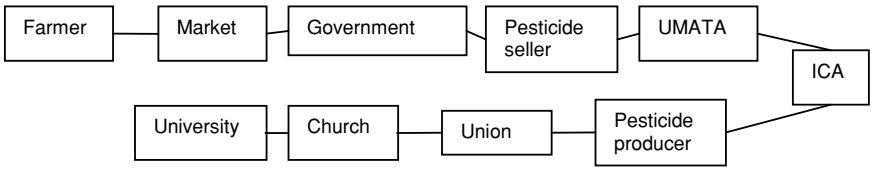

Fig. 3. Generalized expert's agent network.

		Farmers' Element Allocation to Capital Group			
Experts	Element	Human	Health	Natural	Financial
Human capital	Culture	10			
	Education	9			1
	Technical assistance		1	1	**8**
	Religion	8	**2**		
Health capital	Hospital		10		
	SISBEN		10		
	Medical doctors		10		
	Alimentation		9	1	
	Herbal man		9	1	
	Family/kitchen	1	**7**	0	**2**
	Fumigation[a]		**5**	**4**	1
	Pesticide mixing[e]		**5**	**3**	2
Natural capital	Environmental contamination			10	
	Forest			10	
	Infrastructure[b]		1	**1**	**8**
	Biodiversity			7	3
	Water	1	3	6	
	Pests treatment[c]		1	6	3
	Pests treatment[d]		1	**4**	**5**
Financial capital	Income				10
	Credit (access)				10
	Market				10
	Machinery				10
	Land size	1		**6**	**3**
	House (size)	**5**			**5**
	Farming (livestock)			2	8

Table VII. Capital Definition by Experts' and Farmers' Allocation of These Elements to the Capital Groups

[a]Protection while fumigating and mixing pesticides.
[b]Transport.
[c]Gusano blance.
[d]Polilla guatemalteca.
[e]Pesticide mixing.
Note: Large differences are shown in bold; fields in gray scale indicate expected placement.

Second, for experts, *religion* also was considered part of human capital but, interestingly, for 20% of the farmers it comprised part of their health capital. Farmers believed that if they are faithful, God will keep them sane, that is, God will reduce the health risks that might occur when applying pesticides.

4.1.2. Health Capital

Overall, farmers considered health risks of pesticide use to be lower than environmental risks of pesticide use and placed the photographs of *fumigation* and *pesticide mixing* in natural capital (40% and 30%, respectively) instead of health capital. Farmers justified this choice by emphasizing the environmental risks of applying and not applying pesticides. In contrast, experts placed fumigation and pesticide mixing as elements defining the health capital of farmers in the pesticide use context (Table VII).

4.1.3. Natural Capital

In the case of natural capital an overall smaller discrepancy (compared with the other

Table VIII. Different Weighting of Capital Groups

Rank[a]	Farmers Ranking of Own Capitals	Experts Ranking of Farmers' Capitals
1	Health capital	Human capital
2	Financial capital	Financial capital
3	Natural capital	Natural capital
4	Human capital	Health capital

[a]1 = most important; 4 = least important.

capital groups) between experts' and farmers' statements was detected.

Concerning *infrastructure/transport,* experts defined it as an element of natural capital, whereas 80% of the farmers viewed the element as financial capital. To clarify this view, farmers argued that infrastructure is not sufficiently supplied by the state and therefore has to be paid for by farmers themselves. Furthermore, farmers' financial risk increases with lacking and insufficient infrastructure. For example, "bad" road conditions reduce their access to markets, making them dependent on resellers who buy directly from the farm, offering lower prices.

For experts pests such as *gusano blanco* and *polilla guatemalteca* are "insects," and as such are part of natural capital. In contrast, farmers placed *gusano blanco* (50%) and *polilla guatemalteca* (30%) as elements of financial capital, as they associated the pests with high risks of harvest losses and the necessity of costly chemical treatment to minimize these risks.

4.1.4. Financial Capital

In the financial group, farmers' highest deviation from experts' opinion was the element *house/housing*. Interestingly, 50% of the farmers agreed that the house is not a financial stock but a place for meeting and talking. Furthermore, farmers would not try to improve their housing conditions, for example, by renovating their houses or investing in extensions to their houses.[3] *Land size* was placed by 60% of the farmers as part of their natural capital. This choice was explained by the fact that the more land farmers have, the more natural capital farmers feel they possess.

4.1.5. Weighting of the Individual Capitals

As presented in Binder and Schöll,[16] the weighting of the capitals provided first insight into the differences in risk perception between experts and farmers. As documented in Table VIII, experts weighted human capital highest, and health capital lowest. Farmers prioritized health capital over all the other capitals and considered human capital to be the one of least importance. That is, experts consider risks to human capital to be more relevant for farmers' livelihood, whereas farmers consider that if their health is at risk, their whole livelihood might be jeopardized.

This weighting difference can be explained by the fact that experts consider themselves part of human capital, and thus, see themselves as important drivers of the system. Furthermore, the difference in definitions of health capital between experts and farmers was the highest among the capital definitions. As an argument for weighting the farmer's health capital as lowest in importance, experts mentioned that they had observed farmers not taking care of their health and just going to the doctor in severe cases. In contrast, farmers weighted health capital highest, arguing that without "good" health no successful livelihood is possible.

4.2. Part II: Interaction and Dynamics Between the Individual Capitals: The Relational Model

The following section summarizes the differences in experts' and farmers' statements concerning the relational model of farmers' livelihood. The statements are organized by capital. They start with differences in capital state followed by the effect statements made (see Section 3).

4.2.1. Human Capital

4.2.1.1. State. In agreement with the capital weighting, experts considered human capital to be the driver for farmers' livelihood system, impacting on all other capitals of farmers' livelihood. Thus, they stated that all livelihood risks, including those from pesticide application, could be lowered if human capital increased. They were convinced that farmers' human capital is simpler but comparable to their own and that it could be influenced (increased and decreased) to reduce livelihood risks mainly by education, that is, training.

In contrast, farmers did not clearly perceive the state of their human capital and were not even able to explain the composition of their human capital. The origin of their farming knowledge, however, was quite clear to them. Eight of nine farmers said that

[3]It is important to note that the differences among farmers were the highest throughout these statements.

their parents were their main source of information (perpetuating traditions). If their parents did not know how to deal with, for example, a pest problem, 8/9[4] stated that they would ask technical assistance for advice. Yet, two farmers also stated that technicians were not always trustworthy as a source of information as they tended to be subjective and unreliable.

Farmers' perceptions concerning the necessity of pesticide use seem to be driven by the change in crop selection and cultivation practices. A group of farmers argued that over time, due to decreasing crop variety, the incidence of pests in the second cultivation period of potatoes had been increasing. Regarding pesticide use, all farmers (9/9) said that their fathers used sulfur ("sulfato") and lime ("cal") for combating the pests. They claimed that the use of modern pesticides was induced by the abandonment of organic fertilizers and pesticides.

Interestingly, both groups agreed that farmers knew how to protect themselves when applying pesticides, and both groups agreed that this information was "received" and not "searched for," which contrasts with the preferred information source of farmers, namely, their father.

4.2.1.2. Effect statements: Human on natural. The following statements show that experts did not perceive the effect of human on natural capital to be risk-related. Nevertheless these statements reveal that experts can explain an effect from human on natural capital, scoring 2 in the risk perception matrix (see Table IX).

Experts claimed that recommendations about appropriate agricultural techniques would have immediate visible effects on natural capital. Additionally, they stated that farmers not only know their soils (and what their soils need) but also know a great deal about climatic conditions in their region. Some experts additionally argued that small farmers might respect their soils mainly for traditional reasons rather than technical knowledge.

Farmers' statements reveal that farmers perceived and were able to explain the risk related effect of human capital on natural capital. They were even clear about how they would cope with the perceived pest risks (i.e., influencing productivity), scoring 3 (Table IX).

For example, farmers explained that they apply a preventive dose of pesticides throughout every cultivation cycle, following a risk minimization strategy (with respect to productivity). In 8/9 cases, farmers also argued that they immediately increased application frequency upon noticing pest infestation; however, they avoided increasing pesticide concentration because they feared harming the crop. This knowledge was acquired through tradition.

Furthermore, when talking about crop rotation, farmers mentioned similar types of rotations, each finishing with a period of fallow land. The reason for including a fallow period was reasoned with statements like "the soil needs to rest and grass gives it "strength" (4/9). The farmers mentioned noticing that the soil got "tired" and "thinner" if they kept cultivating potatoes and carrots continuously, thus increasing the risks of productivity losses.

4.2.1.3. Human on health. Experts considered that increasing human capital (i.e., understanding the health effects of pesticide misuse) would lead to the adoption of protection measures and thus increase health capital (perception level 3).

Even though most farmers apparently had noticed adverse health effects when applying pesticides, they failed to relate the use of protection measures to a reduction of health risks (scoring 1 in Table IX). This is shown by the fact that eight of nine farmers stated a direct or indirect effect related to pesticide application. Four farmers (4/8) specified lungs, eyes, respiratory system, and suffering from headache and nausea during and after application. But none of the farmers mentioned having noticed a reduction of these effects when using protective equipment.

4.2.1.4. Human on financial. At least for wealthier farmers, experts stated a positive effect of human upon financial capital (score 2, Table IX). Experts stated that wealthier farmers were better-educated farmers, who know whom to trust and whom to pay for technical support. They affirmed that educated farmers have a better position in their social network, and therefore have better access to credit. Their knowledge of the markets, furthermore, provides them with access to better prices.

Farmers did not mention any relationship between human and financial capital, which led to a zero in the risk perception matrix (Table IX).

4.2.2. Health Capital

4.2.2.1. State. In the experts' view the state of farmers health is "bad and at risk" because of, among

[4]Eight of nine farmers answered.

Table IX. Experts Versus Farmers Risk: Perception for Each System Dynamic Effect

	Human Capital (E / F)	Health Capital (E / F)	Natural Capital (E / F)	Financial Capital (E / F)
Human capital		3 / 1	2 / 3	2 / 0
Health capital	0 / 0		0 / 0	0 / 3
Natural capital	0 / 3	1 / 3		2 / 2
Financial capital	3 / 2	2 / 0	2 / 3	

Achieved risk perception levels:
0 = no effect perceived.
1 = effect perceived.
2 = effect explained.
3 = effect perceived is risk related.

other things, inappropriate pesticide use. Farmers defined their health as "good," according to their definition of health capital (see Part I), by the simple fact of being alive and able to maintain their labor productivity and, thus, to support their family.

4.2.2.2. Effect statements. Experts stated that medical support and treatment was sufficient and covered by the governmental health insurance SISBEN (scoring 0, Table IX). Farmers believed that a risk in health capital is directly related to a risk in financial capital (score 3, Table IX). For example, farmers prefer to pay to be professionally and efficiently attended in a private clinic instead of experiencing the inadequate and time-consuming services SISBEN offers for free. Thus in farmers' opinion an adequate health treatment is only assured through financial resources.

Experts argued that farmers were well informed about the health-damaging effect of pesticides and measures to reduce potential health risks, but did not act accordingly. Farmers, however, did not relate their illnesses to inappropriate pesticide use. Additionally, they asserted that none of the medical doctors had mentioned that incorrect pesticide use might be the cause for their sicknesses (scoring 0, Table IX).

4.2.3. Natural Capital

4.2.3.1. State. According to their definition in Part II (see above), experts stated that farmers' natural capital was "good." Nevertheless, they were concerned about future deterioration of the natural capital and thus see a risk of decreasing productivity due to inappropriate management techniques and decreasing farm sizes. Farmers think their soils are "good" but had a limited concept of the "qualification" of soils.

4.2.3.2. Effect statements. *Natural on Human.* While experts did not mention any effect of natural on human capital, farmers tended to learn from their observations of nature (scoring 3). The following statements illustrate this fact. Three of nine farmers answered the question "What effect do you think pesticides have on plants?" with "when dosage of pesticides is high, the growth and the strength of the plant is affected" and "when pesticides are overdosed, burning of leaves is observed." Focusing on the effect of pesticides on biodiversity 5/9 farmers said they had noticed the disappearance of earthworms and other "non damaging insects" in the field.[5]

4.2.3.3. Natural on Health. The element water turned out to be a good "indicator" for understanding the system perspectives of farmers (scoring 3). Whereas 7/9 farmers noticed water contamination by pesticides, 1/7 specified his statement by saying that pesticides could affect water quality because he had observed pesticide residues in the water after applying pesticides. Another farmer (1/7) underscored that the overuse of pesticides could lead to water contamination, causing serious health risks. Three of seven (3/7) farmers explained that pesticides washed off the leaves, percolated through the soil, and reached the aquifer, where they became part of the water cycle. Finally, two farmers (2/7) did not specify further their statements on water contamination.

4.2.3.4. Natural on Financial. From the analysis of the experts' interviews only an indirect statement concerning the effect of natural on financial capital was found: the experts tended to equate "small" with

[5]One of nine farmer stated that pesticides did not affect biodiversity at all, while three of nine (3/9) farmers seemed to have some difficulty in grasping the concept of biodiversity.

"poor" farmers. Farmers, meanwhile, explained that good agricultural production (e.g., soil productivity) would increase their financial capital (scoring 2).

4.2.4. Financial Capital

4.2.4.1. State. Experts did not know anything about the current financial state of farmers. Farmers themselves were also hesitant to rate their financial state as "good" or "bad."

4.2.4.2. Effect statements. As the following statements reveal, the perceived effect of the financial capital on the others also differed considerably between experts and farmers. Experts perceived the effect of financial to human capital as risk related (scoring 3). In contrast to that farmers only scored 2 for financial to human capital but perceived the effect of financial to natural capital as risk related (scoring 3) as the following statements demonstrate. Experts stated that wealthier farmers have more social contacts, care more about the quality of their products, are capable of explaining their problems more precisely, and have more sophisticated agricultural equipment. Experts assumed that these farmers would invest money in sound techniques for potato cultivation. In addition to this, experts think that poorer farmers have minimal financial resources and limited access to credit, "little" natural capital, and are additionally trapped in their social networks. Furthermore, they consider that those farmers are also more suspicious, more traditionalist, more religious, and also reluctant to adopt new technologies.

However, if given the possibility to spend more money, 4/9 farmers would not invest more in potato production, as they fear overproduction and consequently the risk of declining potato prices. Farmers would prefer to try alternative means of income, for example, grow other crops, invest in animal husbandry, or open a fish farm. Only one farmer (1/9) answered that he would try to escape his dependency on climatic conditions by buying parcels in different regions and growing potatoes with different harvest times, thus benefiting from seasonal market-price variations. Confronted with the hypothetical situation of having less money, 4/9 farmers explained that a decrease in their production would result and they would "try to survive this even harder situation." Some farmers (3/9) preferred to take out a loan or to borrow money from a relative or a friend in order to maintain their current living standard.

4.3. Part III: Agent Networks

As shown in Binder and Schöll[16] the comparison of the two agent networks permits the distinction of means and potential for interventions, and represents the social capital of the livelihood in the SMMA analysis. The final experts' network was a straight line: Farmer-Market-Government-Pesticide seller-UMATA-ICA[6]-Pest Producer-Farmers' Union-Church-University[7] (Fig. 3). Farmers' networks were, in contrast, more diverse, as shown in Fig. 4.

Fig. 5 illustrates the differences between the experts' and the average farmer's network (including the standard deviation). Only the relevant differences for risk perception are discussed.

Market. The marketplace, representing customers and intermediaries, was seen by the experts as an element on which farmers depend, whereas farmers seem to perceive that they influence the local prices.

ICA-UMATA. The two governmental technical assistance entities were judged by the experts as having the same importance for the farmers, while farmers clearly feel more connected and supported by the ICA than by the UMATA.

Church. The experts did not believe that faith was an important agent for the farmers, often even forgetting to mention it in their actors list. However, farmers consider the church to be in first or at least third place.

Pesticide producers pesticide seller. Experts place pesticide sellers closer to the farmer in the network, whereas farmers place pesticide producers closer, believing producers to be of more importance to them.

5. DISCUSSION AND CONCLUSIONS

This article applied the method of SMMA[16] to investigate how pesticide management and pesticide risk perception in LDC is related to farmers' livelihood. In doing so, we identified crucial differences between farmers' and experts' mental models, explaining to some extent the lack of success of educational and intervention programs. The differences were made explicit in the SMMA at the level of definition of the individual capitals, ranking of the capitals, system dynamics, and agent networks. In the

[6]Instituto Colombiano Agropecuario (Colombian Agronomy Institute).

[7]The element "university" was just added to allow the farmers to place the interviewers somewhere in the system. Results concerning this agent will not be discussed any further.

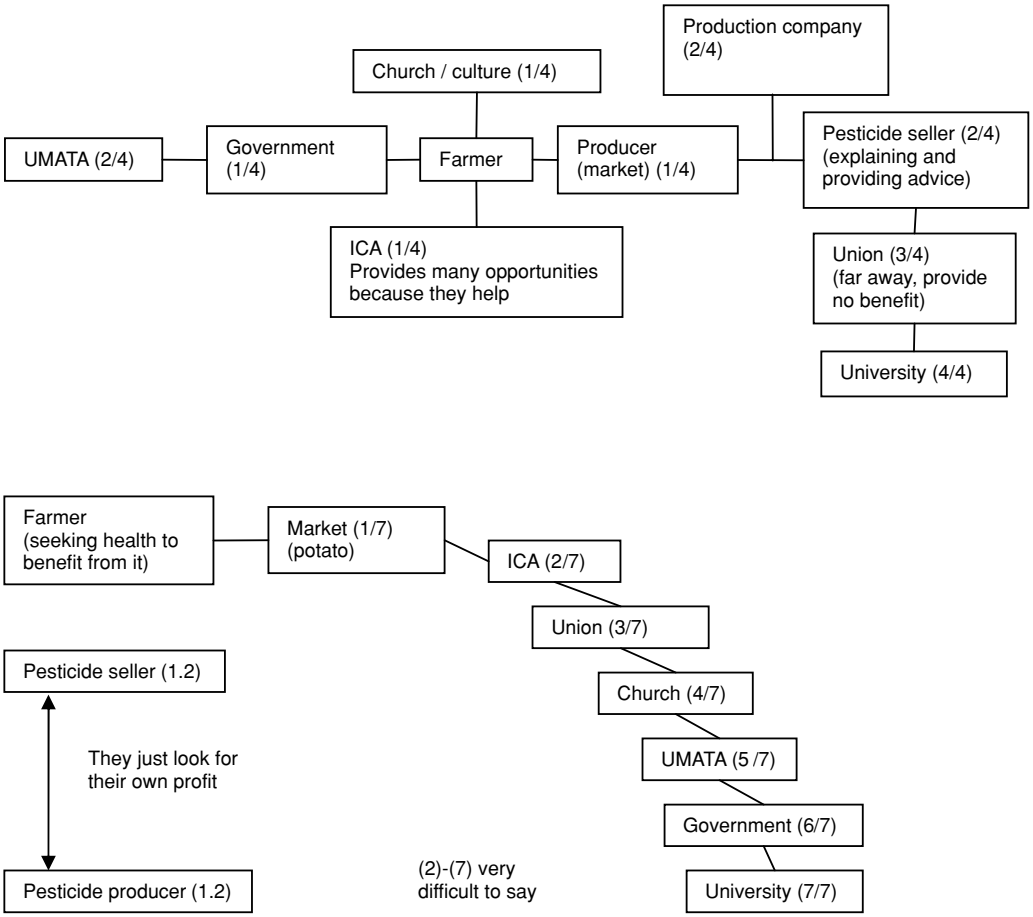

Fig. 4. Examples of farmers' agent networks, where $Y = 4$ in the upper network, and $Y = 7$ in the lower network. For both networks, the distance of each agent in the network is indicated in brackets. For all disconnected agents of the farmers' agent system, the value 1.2 was given.

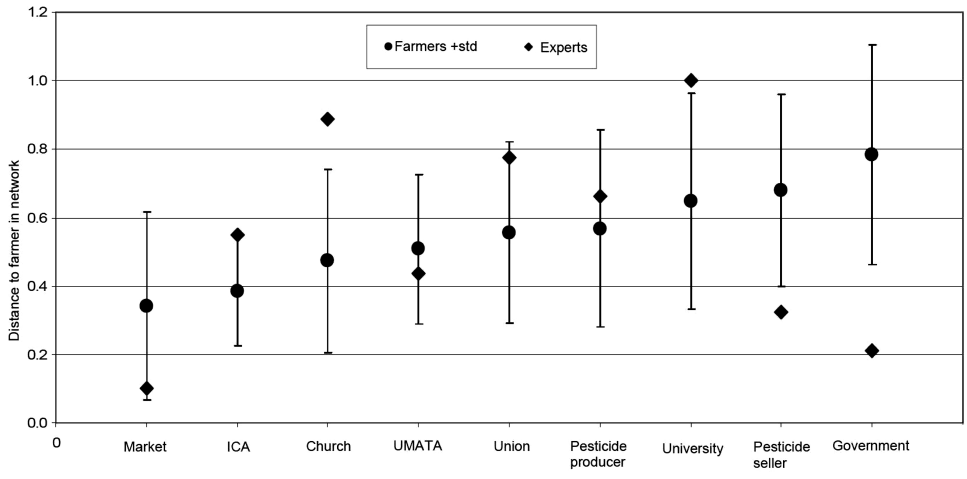

Fig. 5. Difference in experts' and farmers' agent network analysis. (Experts: consolidated; Farmers: with SD.[24])

following, first possible causes for the differences in MMs are discussed. Furthermore, we discuss some strengths and weaknesses of the SMMA, followed by policy recommendations for improving educational programs in the region. Finally, suggestions for further research are made.

5.1. Causes for Differences Among MM

In the following, we discuss three main explanations for the discrepancies between the mental models and risk perceptions of farmers and experts: (i) the role of tradition; (ii), trust in the source of information; and (iii) feedback on knowledge adjustment.

5.1.1. Role of Tradition and Religion

Our results indicate that in the study area farmers have additional sources of information to the ones experts believe they have. For example, religion and tradition significantly influence farmers' risk perception. As presented in Table VIII, some farmers placed the element "church" as an element of health capital instead of human capital. Comparable findings concerning religion and health capital can be found in the anthropological literature.[42–45] Furthermore, this finding is in agreement with Slimak *et al*.,[46] who found that respondents who believed in the literal meaning of religious texts were less concerned about global risk, whereas those who did not believe in an afterlife were more concerned about chemical and ecological risks.[46]

The difference in health ranking can be explained by the different definition of health capital of farmers and experts. While farmers defined health capital in a binary way (i.e., being alive or dead), experts had a more differentiated perspective of health capital as continuous variable of the physical health status. Therefore, experts placed health capital as being least important capital for farmers, as they observed that farmers' activities were reducing their health status. In contrast, farmers stated that if they were dead, they would not be able to work and nourish their family; thus they rated this capital highest. This implies that as long as health is only impaired, health, as defined by farmers, is not affected. Thus health protection information has first to clarify the danger of a product taking farmers' binary health definition into account.

In addition, tradition plays an important role when taking managerial decisions. Farmers agreed that their parents are their main source of information regarding soil and pesticide management. This suggests that management habits are passed on from generation to generation. This finding is in line with the sociocultural perspective, which states that culture and social structures (traditions, religion, and worldviews) might indeed significantly influence the risk perception of agents.[46,47]

5.1.2. Trust in the Source of Information

Farmers' placing of agents in the network was mostly explained by traits of trust, for example, farmers placed pesticide producers closer to themselves than governmental technical assistance, commenting that they had more trust in pesticide producers. This result is affirmed by findings of Trumbo and McComas,[48] which state that information credibility has an influence on risk perception.

Please note that Siegrist and Cvetkovich[49] found high variability in approaches to defining and measuring trust. We concentrated, as set out by Earle and Cvetkovich,[50] on the definition of "interpersonal trust."[8] In our analysis we found three possible traits of trust: (i) contact intensity, (ii) experiences gained concerning the quality of the information given, and (iii) willingness to use information from certain sources.

Regarding the first, contact intensity, findings varied from low (governmental entities) to high (pesticide producing companies). Farmers' statements were always relative, comparing two agents with each other.

Farmers complained that the current contact with governmental entities (e.g., UMATA) was critically low (see Fig. 5: UMATA was placed further away than, e.g., pesticide producing companies). This fact can be explained by substantial reductions in the budget of governmental technical assistance. Nevertheless, an example of a better and more reliable form of governmental technical assistance was the ICA, the technical advisors for animal husbandry. These agents were placed even closer in the agent network than pesticide producing companies and their advice was acknowledged and trusted by farmers.

[8] "Interpersonal trust relates to the perceived presence or absence of particular traits in the source, describing much of the research on source credibility. Social trust, in comparison refers to the complex social processes by which people make choices and assign management responsibilities to individuals, groups or organizations."[50].

However, farmers stated that the contact intensity with pesticide production companies had increased during the last few years, leading to a higher trust in these agents. The high trust given to the pesticide producers implies their responsibility as a source of information for farmers.

Concerning the second trait of trust, we use farmers' judgments on the quality of information inferred from their own experience. Farmers stated they had had "bad experiences," such as crop losses, after following technical advice from governmental entities. Furthermore, the governmental technical assistance seemed to be less informed about health and environmental risks related to pesticide use. In a similar vein, farmers mentioned "testing" generic pesticide products with active components comparable to the ones in "label" products recommended by pesticide selling companies. Farmers learned from those kinds of "self-tests" that "too much of the product burns the crop" and that the dosage must be higher for generic products than for the "label" products.

These results suggest that farmers try to experience the value of the obtained information in order to classify the source of information. They also agree with the assumptions of Severtson,[51][9] who claims that farmers induce a shift from "abstract information from an external sources" to "experimental information."

The third trait of trust, "willingness to use information from certain sources," is exemplified by farmers' and experts' statements concerning the use of the obtained information. This trait of trust is fostered by the former two traits, "intensity of contact" and "experiences regarding the quality of information," but also influences risk perception via one's own independent and heuristic path.

During the interviews, experts underlined their frustration at not being heard by the farmers with statements like "they are just not doing what they were told to do." Farmers said they felt they were not taken seriously by the experts using statements like "we were told to wear protection clothing but not explained why to do so." Additionally, even if farmers had been "explained why they should wear protection clothing," they preferred to ignore the recommendation because the explanation contradicted their own experiences.

[9] "There may be a continuum of informational influences with abstract information from external sources as weaker and experimental information as stronger, and concrete information from external information sources as having intermediate influence."[51]

The effect of ignoring experts' recommendations is explained by Coyle[52] with the term "psychological defensiveness," claiming that "psychological defensiveness is prompted when personally relevant stimuli (information and experience) does not match valued personal goals."

Furthermore, some farmers said they did not trust governmental agencies without giving a particular reason. These statements are comparable to findings presented in the literature review of Trumbo and McComas,[48] reporting that individuals and communities often perceive federal and state agencies as less credible.

5.1.3. Feedback on Knowledge

Feedback on knowledge was found to be an important cause explaining deviations of MMs. The feedback mechanisms analyzed relate to the social amplification of risk introduced by Kasperson.[53]

The best example of feedback is farmers' own definition for their most frequently used pesticides. From former studies,[40] we know that farmers define pesticides as preventive ("preparativo"), cure ("curativo"), or poison ("veneno"), depending on toxicity, price, and use frequency. Toxicity is defined by the effectiveness and bad smell. Indications on the product labels are mostly ignored.

This example suggests that farmers' definitions of products are the result of mainly three mechanisms: (i) intuitive toxicology (i.e., bad smell classification), (ii) experimental knowledge (i.e., experienced effectiveness of a product), gained by applying the product, and (iii) the information formally obtained from the introducer or promoter of a product. The existence of intuitive toxicology is affirmed by studies of Kraus[54] and has no further influence on information processing, such that bad smell is not related to any other recommendation. In contrast, experimental knowledge feeds back on the formally obtained information, leading to a changed MM. This implies that information to which no experience can be related evokes an interruption of this feedback mechanism. Such an example is information on protection measures, in which people are taught to change a habit to avoid a certain not experienced negative effect.

Hence most of the farmers' attitudes regarding pesticide protection measures were referenced to self-constructed safety measures confirming their own beliefs rather then being inferred from experience. These findings are affirmed by Severtson,[51]

who found a wide range of safety thresholds among people commenting on their attitudes related to arsenic risk. Similarly, the findings of Slovic[55] question the rationality of smoking decisions, which in his eyes: "provides a dramatic example of the difficulty that experimental thinking faces in dealing with outcomes that change very slowly over time, are remote in time and are visceral in nature." Furthermore, Lichtenberg[56] underlines that farmers who have experienced adverse health effects of pesticide use care about the effects of application and engage in alternative means of pest management.

It is important to consider that the feedback mechanism can also be interrupted if there is a time delay between action and effect. While experts differentiated between short- and long-term dynamics of the system, farmers seemed to concentrate on the immediate interactions and did not connect earlier actions with time-delayed effects. Nevertheless experts tried to give long-term recommendations (e.g., concerning chronic pesticide risks), neglecting farmers' insensitivity toward this kind of information.

5.2. Improving Risk Communication

Possible recommendations emerging from the three causes of deviating MMs found are presented here, concentrating on the improvement of risk communication.

First, the additional sources of information found, like religion and tradition, should be considered when designing new educational programs. That is, the target population of the planned programs should be clearly defined, aiming at including farmers who typically would be denominated as leaders or who are household decisionmakers.

Second, the credibility of the informer has to be ensured by directly linking the information provided to experience. The Farm Field Schools (FFS) first introduced in Asia[57] are a first step in this direction.

The feedback mechanisms mentioned in Section 5.1.3. should be taken into account especially for the case of pesticide poisoning diagnostics and pesticide safety labeling. Regarding the SISBEN, an improvement in pesticide poisoning diagnostics and an obligation to carry out poisoning notifications could directly raise the application of pesticide protection measures. Regarding label improvements, the current toxicity rankings of pesticide producers should be linked to farmers' definition of pesticide toxicity ("preparativo," "curativo," "veneno").

5.3. Strengths and Limitations of SMMA

We consider that the strengths of SMMA are that it provides: (a) a structured analysis of the risk perception problems in LDCs along with their possible causes; (b) an understanding of the relevance of cultural elements in reasoning; (c) an approach to understanding the relevance of different risks in relation to farmers' livelihood; and (d) an analysis of potential causes for differing MMs leading to new options for improving risk perception and risk communication.

From the application of the SMMA, we consider that possible limitations of the approach are that: (a) the differing opinions of experts, specially experts of different fields of competence are difficult to compare; (b) the selection of the experts is critical for the success of the analysis; and (c) an additional second interview of the experts on the basis of farmers' statements could bring additional information and insides.

5.4. Further Research Applications

The next step of our research will be to validate the obtained results with an extensive survey in Vereda la Hoya. Since the SMMA is a new method some aspects could be improved and additional applications can be envisioned.

As our approach required the knowledge of different scientific expert groups, one interesting question could be to which extent these experts also differ regarding their mental models. This information would help to consolidate the developed ideas on improving risk communication.

Our research showed the relevance of agent networks for planning successful interventions. In a next step, this analysis could be further developed by establishing an agent network, characterizing also the strength of the agents' interaction. This network should be developed together with the involved agents and validated with other farmers in the region.

One possible further challenge is to develop a culture-specific typology of farmers, comparing, for example, smallholders in Latin America, Asia, and Africa. This typology would allow to specify intervention programs according to similarities and differences among these cultures. As mentioned before, an adaptation to the culture-specific cognition patterns would be required.

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Paper 3

Comparing system visions of farmers and experts

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Comparing system visions of farmers and experts

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A B S T R A C T

The goal of this paper is to identify farmers' future in terms of the pesticide management of potato growing farmers in Vereda la Hoya (Boyacá, Colombia).

To achieve this goal we applied the Future-Structured Mental Model Approach (Future-SMMA) and interviewed 10 farmers concerning their future perspectives and expectations to derive their future visions. Subsequently, 10 experts were interviewed about the feasibility and the consequences of farmers' future visions.

Applying the Future-SMMA, we analyzed farmers' future visions and found that farmers take account of social and environmental threats and that their visions are optimistic. In addition we compared farmers' and experts' perceptions of external constraints on farmers' future and discovered that the future visions of farmers and experts were inconsistent. Finally, we determined how farmers' livelihood assets and self-perception influence the formation of farmers' future visions and found that the more a person was able to differentiate his livelihood assets the more differentiated were the future visions of that person.

In discussing our findings, we deduce that the inconsistency of future visions found is due to diverging attitudes towards future scenarios and differing opinions about who should take responsibility for the knowledge management of farmers.

1. Introduction

Despite considerable improvements in food production over the last 50 years, food security remains a problem in many parts of the world [1,2]. According to the latest estimations of the Food and Agriculture Organization of the United Nations (FAO) 852 million people were undernourished between the years 2000 and 2002. Pesticides, once praised as yield savers, securing harvests in quality and amount [3], and thereby regarded as crucial to feeding the growing world population, have failed to fulfill expectations [1].

Furthermore, despite improvements in plant protection [1,3] the control of plant pests[1] still entails substantial use of pesticides, which have been shown to cause a variety of unexpected negative side effects on the environment [4–8] and on human health, not only of pesticide users but also of consumers of contaminated goods [4,9–11]. Ongoing misuse of pesticides continues to deplete soils and destroy biodiversity [12] and these effects are expected to worsen in the future [1]. Farmers, especially in less developed regions, seem to be unaware of these effects as they continue to misuse pesticides despite an observed deterioration in their means of subsistence [13,14].

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[1] Pests: Plant pests, which include insects, pathogens and weeds (''pest'' is used as defined in the International plant Protection Convention: ''pest - any species, strain, or biotype of plant, animal or pathogenic agent injurious to plants or plant products''), continue to be major constraints on food and agricultural production in many regions of developing countries [1].

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How will the pesticide application saga continue? Where is agricultural production technology heading? What underlying factors determine this development? The future of agricultural production is closely connected to the future of farmers producing agricultural products. For the purpose of our research we have focused on the viewpoint of farmers and their future. The future of farmers is determined by a wide variety of factors. We grouped the factors determining farmers' future into two subgroups according to different types of influence: external factors and internal factors. What we mean by these influences, the existing research on the future of these influences and their interplay in determining farmers' future will be explained in the following two sections, the first referring to external and the second to internal-factors.

1.1. External factors influencing farmers' future

The term external factors refers to factors like environmental conditions (climate, pests, soil quality) or structural factors (technical advisor organizations or the development of agricultural markets), which influence farmers' future but develop independently of farmers' wishes, i.e., factors which cannot be controlled by the farmers.

With reference to this definition, farmers' future will be determined by four major external factors: (1) changing climate [1,15]; (2) the spread of pests throughout the world [1]; (3) changing agricultural markets reshaped by the demand for organic food and bio fuels [1]; and (4) changing agricultural technologies, e.g., an increasing degree of mechanization or the use of genetically modified plants [16].

External factors constitute possible external constraints on farmers' future and these are best known to experts like farmers' technical advisers, extension officers and governmental agencies [17]. Moreover, local experts' perspectives on farmers' livelihood reveal exactly how external factors contribute to farmers' future. Local experts are even in a position to distinguish whether external factors influence farmers' future directly or indirectly via changing farmer livelihoods, which in turn influence farmers' future.

Even though local experts determine to a large extent how and what type of information regarding external changes reaches farmers, they have rarely been the objects of research [17]. To the knowledge of the authors external factors influencing farmers' future have neither been analyzed through the eyes of local experts who advise farmers nor in the context of farmers' livelihood assets.

1.2. Internal factors influencing farmers' future

Similarly to the external factors presented above, internal factors have to be borne in mind when investigating farmers' future. In contrast to the external factors, we use the term internal factors for factors which are directly determined by the farmers themselves, like farmers' education, perception or decision-making.

The importance of internal factors for agricultural development has been stressed by several research groups, especially while trying actively to influence agricultural development. The influence of agricultural development encompasses situations in which there are major differences regarding perceptions of the nature of the problem, the need for action and what type of action should be taken. Research on integrated resource management emphasizes the need to develop methods combining approaches from soft[2] and hard[3] system analysis [18]. According to the studies of Ross [19] and Ryder [20] farmers have to be actively involved in the decision and developing process of development projects in order for their development to be facilitated toward more sustainable agriculture. Furthermore other researchers report that in the past, many local development projects failed, because they did not address the needs identified by the target communities themselves. The projects imposed solutions that were not perceived as relevant by local people and were consequently abandoned [21,22]. Additionally Lynam et al. [23] and Ramirez [24] found that there is increasing recognition that positive changes are more likely to be initiated when the attitudes, beliefs or preferences of the people managing or depending on resources are considered in the identification of problems and the development of solutions.

The internal factors can be roughly divided into four groups: first farmers' livelihood assets, second farmers' self-perception,[4] third farmers' behavior[5] and fourth farmers' future visions. The "livelihood assets"-factors determine the flexibility of a farmer in acting on or reacting to changes in external factors. The "self-perception"-factors determine how farmers calculate their present position and the "behavioral"-factors determine how they actually act on/react to a change (but will not be further analyzed in this study). Finally, farmers' future vision-factors include farmers' expectations and perspectives for the future and farmers' future scenarios. Therefore farmers' future vision-factors determine what position in the future farmers are hoping for. In other words, how well farmers cope with future challenges will depend on the condition of "livelihood assets", "self-perception" and "behavior". And, finally, what they are willing and prepared to confront will depend on future visions.

[2] Soft system analysis focuses on the importance of subjective perceptions and socially constructed reality. It combines two concepts: "mental models (referring to a specific mental representation of information about reality)" and "frames (referring to the context in which such a mental model is embedded and which gives sense and meaning to it)" [18].

[3] Hard system analysis focuses on the importance of the factual knowledge basis [18].

[4] How the farmer perceives his surroundings, himself and his abilities.

[5] This definition of behavior includes attitudes and decision-making [58].

To the knowledge of the authors no studies so far have been conducted specifically targeting farmers and farmers' perspectives on future pesticide application. The studies focusing on future visions in general give indications about points to consider when farmers and problems involving rational thinking are to be investigated. These epistemological indications are of the nature of internal factors like the ones presented above.

For example the influence of internal factors on people's future has been widely discussed in the epistemology of Future Studies among others by Innayatullah [25], MacKay and McKiernan [26] and Aligica [27].

Innayatullah [25] present three ways to frame the future and future studies: predictive/empirical, interpretive/cultural and critical/postmodern. The internal factors are representatives of the interpretative/cultural frame and are especially important for farmers.

MacKay and McKiernan [26] focuses, in his epistemology of future studies, on cognitive linkages between past, present and future. Past experiences are stored within farmers' livelihood assets in the form of human capital which according to MacKay and McKiernan [26] influences farmers' future visions. He analyses the role of hindsight in foresight and stresses the importance to consider psychological biases in scenario thinking.

Aligica [27] demands an epistemology of prediction as a part of Future Studies and its consequences, giving an additional argument for the importance to consider livelihood knowledge in the construction and understanding of future visions. He emphasises that the social aspect of prediction represents the difference between explanation and prediction. Aligica concludes that background information and personal, local and tacit knowledge play a major role in predictive arguments and procedures and such that they have to be consider in the construction and analysis of future visions.

Also Rubin and Linturin [28], Chenoweth et al. [29], Quinn et al. [30] and Chaves and Riley [31] base their analysis of future visions on the premise that internal factors influence future visions.

For example self-perception is represented in Rubin's Future Image Index Map [28] by general knowledge and social knowledge elements such as general beliefs and ethics. In Rubin's tool these elements are considered to influence the build up of future images (which we call future visions in this paper). In addition some livelihood assets like gender, skills and profession are represented in Rubin's tool by the elements of identity. However other livelihood assets such as financial or natural capital are not considered in her tool. These may not be important to compare teachers and adolescents' future images but play a key role in farmers' future images and therefore should be considered.

Similarly Chenoweth et al.'s [29] research on the future visions of students, revealed that environment and past experiences of students influenced their understanding of the future.

Likewise Quinn et al. [30] shows that people's perception of future problems depends not only on the environmental condition they live in but also on their social situation and livelihood strategy. He stresses that to incorporate livelihood knowledge, not only the perception of local communities has to be considered but also the livelihood context itself. Regarding pesticide use in particular, farmers' local knowledge has been shown to provide information about their awareness of pesticide effects, but the effect of local knowledge on future visions has not been investigated so far. Research on people's future visions has hardly ever been applied to farmers and their future.

Diverse attempts have been undertaken to investigate and derive peoples' future visions and their influence on peoples future. Known methods for assessing future orientations are: AgFutures a decision support tool to develop sustainable agricultural futures [32], Future Image Index Map method [28], the Foresighting Workshops method used by Chenoweth et al. [29] developed by the UK foresight program [33] and Future Search [34]. Results from these research programs have shown that the awareness of future visions also influences the future itself. But the approaches presented have not explicitly incorporated the effect of livelihood assets on future visions and have not yet been applied to assess neither farmers' future nor the future of farmers concerning pesticide application.

1.3. The Future-Structured Mental Model Approach

One method for analyzing farmers' livelihood assets, farmers' self-perception and farmers' future visions together with experts' views is the Structured Mental Model Approach (SMMA) developed by Binder and Schöell [35] and first applied by Schöell and Binder [36]. The SMMA method combines the Mental Models Approach (MMA) [37,38] with the DFID Livelihood Framework [39].

The SMMA was originally developed to integrate farmers risk perception in the framework of their livelihood assets and to compare this perception with the evidence-based risk assessment derived by local experts. So far the SMMA has been applied in analyzing risks concerning pesticide management [36]. For this first application the DFID Livelihood Framework was slightly adapted to the needs of a health risk focused problem such as pesticide management. That is, health was defined as a distinct livelihood capital in addition to the capitals used in the DFID Livelihood Framework. For the purpose of this research, the SMMA tailored to pesticide management was adapted to investigate the future of pesticide management. By adapting the focus from "present risk perception" to "future visions" we consider that the SMMA is an appropriate tool to derive farmers' "self-perception" in the frame of their "livelihood assets" and to compare these findings with the view of experts. In the remaining parts of the paper we refer to the method applied as "Future-Structured Mental Model Approach" (Future-SMMA).

The Future-SMMA determines what agricultural future farmers and experts expect based on the development of the assets of farmers' future livelihoods. Furthermore, it allows for analyzing how farmers "livelihood assets" and "self-perception" influence farmers' future visions and farmers' future.

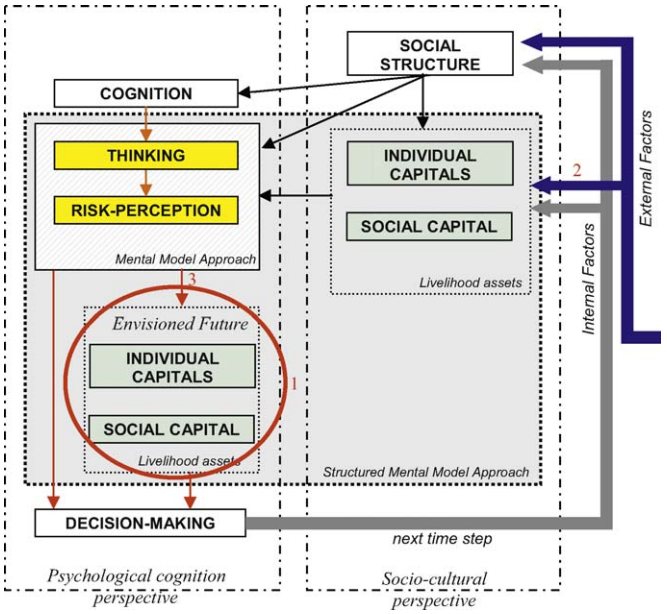

Fig. 1. Research aims within the SMMA theoretical-framework [35] 1 = farmers' future visions in the context of their livelihoods, 2 = future external constraints in the context of farmers' livelihood, 3 = how farmers' livelihood assets influence the construction of farmers' future visions.

The goal of this paper is to identify farmers' future in terms of the pesticide management of potato growing farmers in Vereda la Hoya (Boyacá, Colombia). To achieve this goal the authors applied the Future-SMMA in order to:

(1) Investigate farmers' future visions in the context of their livelihoods.
(2) Compare farmers' and experts' future visions and perceptions of external constraints on farmers' future.
(3) Determine how farmers' livelihood assets and self-perception influence the build up of farmers' future visions.

Using the SMMA theoretical framework the three aims of the study are presented in Fig. 1.

The structure of this paper is as follows. Initially, the study area is presented followed by an outline of the "Future-SMMA"-method. Subsequently, the results of the Future-SMMA are presented. Finally, in a Section 5, the results are summarized and the consequences of these results for the future of farmers are outlined.

2. Study area

The selected study area Vereda la Hoya is located in the rural part of Tunja, the capital of the Departamento de Boyacá (Colombia). La Hoya ranges from 2700 m to 3250 m a.s.l., and has an area of 8 km^2 (840 ha), an average temperature of 12 °C, and a population of about 747 inhabitants (130 families). The main source of income is farming. Farmers cultivate minifundios, with an average size of 6.6 ha [40,41]. The land use pattern in the year 2004 was: crop production 40%, animal husbandry 25%, fallow land 33%, and forest 2%. The main agricultural crops grown in la Hoya are: potato 27%, vetch (carrots) 23%, corn 18%, horse bean 18%, wheat 9%, and onion 5%. Usually the land is cultivated in two cycles a year (September to February and March to August), which permits two harvesting seasons. The typical rotation consists of 2–3 cycles of potato, 1–2 cycles of carrots, and 2–4 cycles of fallow land. In Colombia, agriculture accounts for 21% of the GNP and 40% of the labor force [42,43].

Potato production in la Hoya is vulnerable to three major pests, the soil-dwelling larvae of the Andean weevil (*Premnotrypes vorax*, "Gusano blanco"), the late blight fungus (*Phytophthora infestans*, "Gota"), and the Guatemalan potato moth (*Tecia solanivora*, "Polilla Guatemalteca"). Farmers and agricultural scientists alike consider insecticides and fungicides necessary for the control of these pests. Up to 12 applications of each are required [44]. In our study region the predominant pesticide used for potato production is carbofuran (an insecticide and nematicide; potential health effect: respiratory system failure) followed by mancozeb (a fungicide; potential health effect: sensitization rashes) and methamidophos (an insecticide; potential health effect: delayed neurological problems) [40,45–50].

A number of educational interventions were organized in the region by pesticide selling companies and governmental agencies during the years 2006 and 2007. Two agencies, CORPOBOYACA[6] and CORPOCHIVOR,[7] aim at securing the watershed management of the Chicamocha river (ensuring constant water quality and quantity for the water reservoir of an energy

[6] CORPOBOYACA = Corporación Autonoma Regional de Boyaca (Independent regional cooperation of Boyaca).
[7] CORPOCHIVOR = Corporación Autonoma Regional de Chivor (Independent regional cooperation of Chivor).

Table 1
The three analytical parts of the Future-SMMA.

Future-SMMA	Farmers' model of their desired future livelihood	Experts' model of farmers' possible future livelihood
Part I	Construction of desired futures (first in general, subsequently for the year 2017)	Discussion of farmers' desired futures
	Discussion of feasibility of four (previously constructed) future scenarios	Discussion of expected preferences of farmers concerning the four future scenarios
	Preference ranking these four future scenarios	Feasibility ranking of the four future scenarios
Part II	Answering open-ended questions about the relations of the capital groups with respect to the farmers' preferred future	Elucidating how the key capital elements will develop by 2017, by naming three expected stages of development for each element[a]. The levels were: (1) best case, (2) an intermediate case and (3) worst case
	Naming whom they will turn to for help to achieve the desired future	Naming own role and plans concerning agricultural development projects
Part III	Designing future agent network[b]	Discussing the future agent network of farmers in relation to farmers' future

[a] These elements were selected as being key to the system by experts and farmers in a WS on an earlier occasion.
[b] The future agent network was derived from an earlier network the farmers drew in an earlier interview campaign.

plant). A further agency, UMATA,[8] tries to promote the development of cooperatives to secure a sufficient supply for three governmentally organized potato washing points.

3. Methods

3.1. The future-SMMA method

The Future-SMMA method is an adaptation of the SMMA [35,36]. It was developed to investigate farmers' and local experts' perception of the future of the agricultural system in general and for a timeframe of 10 years, i.e., until 2017.

It differs from the SMMA in two main aspects:

(1) In the Future-SMMA, the farmers are interviewed first. The experts' interviews are built on the findings of the farmers' interviews.
(2) For the Future-SMMA all the questions of the SMMA interview were reformulated to reflect the viewpoint of the future. That is, each present-question was reformulated as a future-question.[9]

The Future-SMMA consists of a prerequisite phase and three analytical parts, namely: (i) definition and ranking of possible futures; (ii) potential effect of these futures on farmers' livelihood; and (iii) future agent network (Table 1).

3.1.1. Prerequisites

As in the SMMA we consider that five types of capital define the livelihood of a farmer: human, health, natural, financial and social capital. Each type of capital is composed of several elements which were previously defined together with experts and farmers in the region. The definition of the capitals and the element allocation for the study regions [36] are presented in Table 2.

3.1.2. Part I: definition and ranking of possible futures

The goal of this part is to first obtain an idea of farmers' general view of the future; and second to prioritize four futures that farmers envision. The latter were defined and weighted first by farmers, then by experts.

3.1.2.1. Farmers' interview. Initially, farmers were asked to talk about a desired future from a broader perspective. Then, the question was narrowed down to a future timeframe of 10 years, i.e., the system state in the year 2017. Subsequently, four scenarios (Table 3) were shown to the farmers, which had been developed by the interviewer beforehand,[10] and the farmers were asked to discuss their feasibility. Finally, farmers were asked to rank the 4 scenarios in order of preference.

3.1.2.2. Experts' interview. The future expectations of farmers obtained as described were summarized as preparation for the expert interview. Initially, experts were asked to comment on the general future scenarios farmers had developed. Afterwards, they were shown the same four scenarios (Table 3), and asked to discuss them according to the preferences they expected the farmers would have. Subsequently, farmers' rankings of the four scenarios were shown to the experts and the experts were asked to comment on it. Finally, they were asked to rank them with respect to their feasibility.

[8] UMATA = Unidad Municipal de Asistencia Técnica Agropecuaria (Municipal entity of agricultural technical assistance).
[9] For instance, the question "Do you think that the soil quality is damaged by the use of pesticides?" was reformulated as "If you changed the application technique of pesticides (like reducing the amount), what do you think would happen to the quality of your soils?".
[10] Derived from informal meetings with the farmers and from considering recent governmental efforts in the study region as well as from ideas developed in cooperation with an ethnological study conducted in the study area (October 07–March 08) [60].

Table 2
Definition of the four individual capitals, the social capital and capital related system elements.

Capital	Definition	System element	Definition (as defined by the interview participants in a preceding work shop (2005))
Human capital	People and their ability to be economically productive. It includes educational level, skills, experience, knowledge, creativity and innovativeness [61]	Education	Education is a way of living, obtaining knowledge and training for personal improvement (personal best), influencing the community by transmission of specific knowledge. It is the package of knowledge transmitted for the personal formation of the community
		Tradition	Customs, myths, cultural values and crafts inherited and learned from our ancestors
Health capital	The level of healthiness that allows a person to perform his or her economic and social activity (own definition) [35,36]	Pesticide management	Process of activity to apply the product by recommendations and/or customs in the use of the pesticides to control and prevent plagues and sicknesses
		Alimentation	Consumption of elements or products which give energy and force to living beings for the development of their functions
		Housing	A place of refuge (shelter) and habitation to share all types of relations as a basis for development of the individual and his/her family
Natural capital	The natural resource base available for pursuing an agricultural activity. It includes land and soil quality, access to water, etc. [61]	Soil	Resource of the environment, basic for agricultural and animal husbandry production
		Water	Necessary resource for all activities of life, whose economic value has not been recognized
		Forest	Natural space and symbol of life, fundamental to maintaining an equilibrium of natural resources
		Livestock	Economic activity of breeding, raising and obtaining sub-products from diverse types of domestic animals (livestock)
Financial capital	Money, machinery, tools, equipment and buildings needed to produce goods and services and to live [62,63]	Market	Space were producers, middlemen and consumers converge to stock up and sell products, achieving an economic benefit
		Harvest	Productive system established by means of familiarly forces in order to obtain a benefit
		Agricultural technology	Mechanical, hand made and/or systematized tool that facilitates the productive process, saving time, money and labor (manpower)
Social capital	Process of social networking among people that leads to accomplishing a goal of mutual social benefit, usually characterized by trust and involvement in the community [61,63]	Agents of the network	Church, Government, ICA, Market, Pesticide seller, Pesticide producer, University, UMATA, Union

Table 3
Description of the four scenarios presented to farmers and experts.

Future	Characteristics
Cooperative	Creating a farmers' cooperative. The cooperative could improve (a) irrigation systems, (b) seed quality and (c) bring unaffordable technology to the farmers (like their own washing station for carrots)
Technical training	Training courses farmers could attend. Possible topics of the courses could be: how to handle pesticides, how to protect personal health and crop quality The courses could be taught in the form of lectures or farm field schools The courses could be taught to a farmers' assembly and could be provided by known technicians, or sellers
IPM[a]	Try to move toward decreasing use of pesticides. A step further in this future scenario would even imply trying to abandon pesticide use entirely and to practice organic farming
Status quo	La Hoya stays like it is

[a] IPM abbreviation for Integrated Pest Management, pest control strategy that uses an array of complementary methods: natural predators and parasites, pest resistant varieties, cultural practices, biological controls, various physical techniques, and the strategic use of pesticides [64,65].

Table 4
Ten open-ended questions from farmer interview part II of Future-SMMA.

System element	Ten open-ended questions
Livestock Tradition Harvest	In view of the desired future, how would the traditional method of potato cultivation change? ...the way potatoes are produced or the quantity which is produced? What would happen to the other work you do, other crops you produce or your animal husbandry?
Education Agricultural technology	How should the education change?...what ability do you lack to change or improve the way you cultivate? Would you need more mechanization (more technical equipment?) a new plough (''renovadora de suelos''), a tractor...?
Tradition Pesticide management	Would the traditional way of cultivating potatoes change (compared to the way your fathers did it or taught you)? Would the ''tradition'' or method of using pesticide in cultivating potatoes change? Would it have to change?
Pesticide management	How would the handling of pesticides change? What would you do in the desired future if infestations occurred? Would you predict more or less infestations than nowadays? Would new pests arise?
Water Soil Forest Agricultural technology Livestock	How would the quality of your water change?...if you changed your cultivation technique? How would the quality of your soils change? Would you continue to cultivate in cycles (why)? How would the forestes of the vereda change?
Pesticide management	What would you ask the technician about security issues (or appropriate handling) of new products or new techniques of applying pesticides? Would you change (adjust) the way you protect yourself while applying pesticides,...why...?
Harvest Market	How do you expect the harvest to change? To whom would you sell your products? Would you sell alone or in cooperation?...together with a person that helped you reach your desired future?...or half alone-half in cooperation ?
Market	How do you think the (product) market (markets) will change? How would the markets change with in your desired future? Will the prices change,... why? ...how?
Alimentation Housing Tradition	How will your house change? How will your food change?... will your customs concerning alimentation change? ...how?
Housing Agricultural technology	What would you do if you had more money?

3.1.3. Part II: potential effect of farmers' future visions on farmers' livelihood

The goal of this part is first to understand how farmers perceive the consequences of their visions for the future on their current situation from a system development perspective. Second, it aims at obtaining local experts' views on the constraints farmers might face in reaching their preferred future.

3.1.3.1. Farmers' interview. Farmers answered 10 open-ended questions about the relations of the elements of the capital groups with respect to their preferred future selected in part I. The questions and the relation between the questions and the capital groups are depicted in Table 4. Subsequently, the farmers were asked whom they would ask for help to reach their desired future. This question was designed to find out if the farmers would mention one of the interviewed experts as their direct ''helping hand'' to achieve the desired future.

3.1.3.2. Experts' interview. Experts were asked to elucidate how the system elements (Table 2) would develop by the year 2017 by naming three expected levels of development for each element. The levels were: (1) best case, (2) intermediate case and (3) worst case. For example, for the element water the experts were asked: ''What will the water quality and quantity of the region (Vereda la Hoya) be in 10 years? What is the best water condition you can envision? What is the worst? What is a possible ''intermediate condition between the two?''

Subsequently, they were asked to talk about their own projects (concerning educational or development plans) which might affect farmers' future. Finally, the experts were asked if they were planning to coordinate their projects with any other agency in the region.

3.1.4. Part III: future agent network

The goal of this part is to obtain an agent network that reflects the relative importance of agents necessary to achieve farmers' envisioned future. The agents were selected before the interview, preferably in experts' and farmers' interviews [35,36]. Finally, farmers and experts were asked if any agents should be omitted or added to the agent network.

3.1.4.1. Farmers' interview. Farmers had to depict their future agent network by placing 10 photographic representations of agents in relation to themselves. The closer an agent was placed with respect to the farmer, the more important the agent was for achieving the envisioned future.

Table 5
Overview of possible capital states of the interviewed farmers.

Capital[a]	High (state)	Low (state)
Human	Education: 8 years of primary school	Education: no formal education
Health	No specification[b]	No specification[b]
Natural	Soil: fertile soils	Soil: less fertile soils
	Slope: low	Slope: high
	Forest: owns land with natural forest	Forest: does not own any land with natural forest
Financial	10 ha of own land	Landless farm worker
Social	Status: community leader	Status: isolated member of the community

[a] Covering the livelihood of farmers; see Section 3 for definition.
[b] As there was no information about health effects related to inappropriate pesticide use, the farmers could not be selected by their difference in health capital state.

3.1.4.2. Experts' interview. The experts were initially familiarized with the pictures of the agents and asked to construct the network they thought would be helpful for farmers in reaching their desired future.[11]

3.2. The subjects

For the study 13 experts and 10 local farmers were interviewed in the Future-SMMA.

3.2.1. Farmers

The 10 farmers interviewed were all male and between 24 and 40 years of age. They were selected by purposeful sampling from different parts of the study region, and covered all kinds of livelihoods in the region by differing in characteristic elements of the farmers' livelihoods. That is, the livelihood of the selected farmers covered different states of human, health, financial, natural and social capital (Table 5).

All participants were familiar with the system element definitions used in the interview, e.g., 7 of the 10 chosen farmers already had participated in the preceding SMMA-study [36]; 3 of the farmers had participated in a system analysis workshop held in the region in 2005.

By covering all forms of livelihood-capital combinations we aimed at covering all kinds of mental models in the area. Moreover following the Maharik et al. [51] study we limited the farmer sample to 10 participants, as throughout the Future-SMMA the characteristic drop off of new concepts was observed after interviewing 4–5 farmers.

3.2.2. Experts

The sample of 13 experts consisted of 5 females and 8 males, half of whom were between 30 and 40 years of age, and half between 40 and 50. In order to cover all important experts' mental models relevant to farmers' future a combination of professionals from different scientific fields of the system being analyzed were selected [35]. The experts group included: representatives of pesticide producers, i.e., pesticide sellers, representatives from governmental technical assistance institutes and health ministries, toxicologists, medical doctors, economists and an agronomist. Two of them had been locally involved, five had a regional perspective and six worked at a national level (Table 6).

The experts differed in the following criteria: (i) knowledge of the local, regional, or national system; (ii) expertise in different aspects of the livelihood system; (iii) hypothesized position within the farmers' agent network.

By covering different ranges of these criteria we also aimed at considering different influence options concerning existing and planned policy interventions.

Ten experts already had participated in the preceding study and were familiar with the system elements definitions. Three experts had just started as technical advisors in the region in winter 2006/2007 and were expected to have an influence on farmers' future within the selected time frame.

3.3. Analysis

The results of the Future-SMMA were analyzed and structured according to the three steps of the method mentioned above. In each of the interview parts answers from the farmers' interviews were analyzed and summarized to provide an overview. This overview was used as a basis for the experts' interviews, to optimally target their expert perspectives with respect to farmers' views. Originating from the MMA [38] agreement among the expert statements should be

[11] The corresponding question in the experts' interview was: "If the farmer was here, place the agents depicted in the photographs around him by considering how important you think they are for the farmer in reaching his desired future. Can any agents of the former network be omitted and why? Are there any agents missing in order to attain the desired future? Which ones and why?".

Table 6
Overview of interviewed experts.

Age	Gender	Education	Profession	Working entity
30–40	f	Agricultural engineer	Pesticide seller	Regional level
30–40	f	Toxicologist	Laboratory technician	National Health Institute[a]
30–40	m	Toxicologist	Laboratory technician	National Health Institute[a]
40–50	m	Chemist	Laboratory technician	National Health Institute[a]
40–50	m	Economist	Professor	University[b]
30–40	f	Microbiologist	Laboratory technician	National Health Institute[a]
30–40	f	Agronomist	Private technical assistance	Independent regional cooperation of Boyaca[c]
30–40	m	Agricultural engineer	Private technical assistance	Independent regional cooperation of Boyaca[c]
30–40	m	Agricultural engineer	Professor	University[d]
30–40	m	Agricultural engineer	Public technical assistance	Municipal entity of agricultural technical assistance[e]
40–50	f	Medical doctor	Pesticide stewardship	National level
40–50	m	Economist	Professor	University[d]
40–50	m	Medical doctor	Medical doctor	Hospital St. Raphael

[a] Instituto Nacional de Salud, INS.
[b] Universidad de los Andes, Bogota.
[c] Corporación Autónoma Regional, CORPOBOYACA.
[d] UNIBOYACA, Tunja.
[e] Unidad Municipal de Asistencia Técnica Agropecuaria, UMATA.

reached, yielding one comprehensive statement, and the farmers' diverging statements then compared to that single expert MM.

3.3.1. Analysis part I

The farmers' future expectations were analyzed with respect to the four futures prepared beforehand, each representing a different perspective of farmers' possible future (Table 3). In a similar way experts' comments were summarized and compared to farmers' statements for each of the four futures.

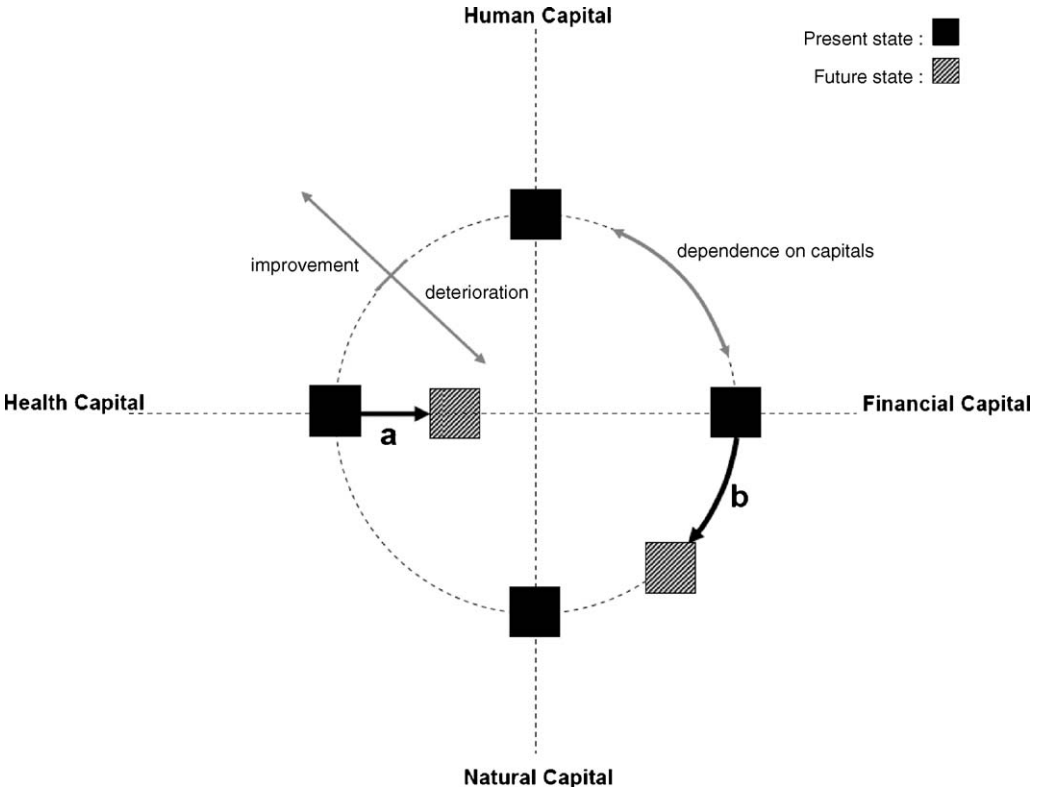

Fig. 2. Example of system dynamic graph: (a) demonstrates how the future state of the health capital is placed if the capital is expected to deteriorate in quality and at the expense of no other capital; example (b) demonstrates that the financial capital is expected to become more dependent on natural capital (graphically the distance between the two capital states decreases).

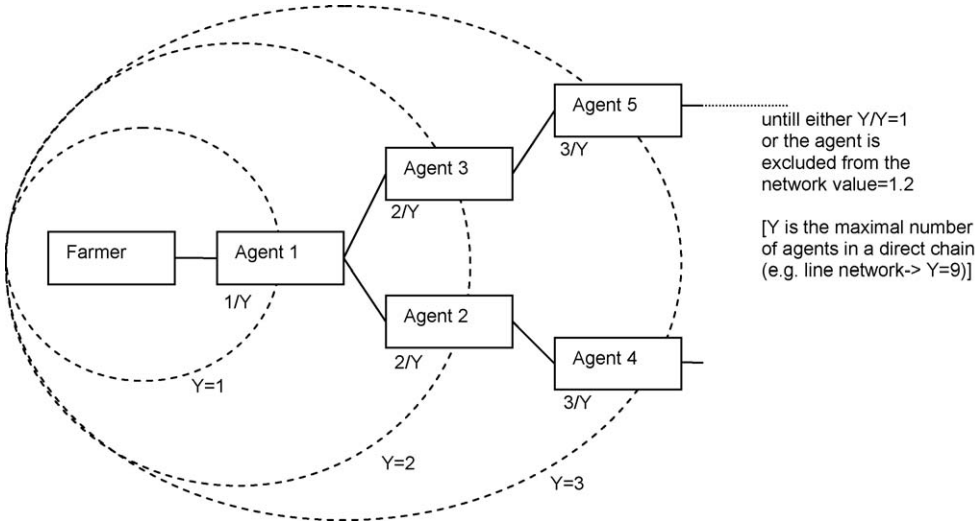

Fig. 3. Agent network analysis [36].

3.3.2. Analysis part II

The second part of the analysis concentrated on comparing farmers' and experts' statements in the livelihood frame. Hence we compared the system dynamic of the cause-and-effect thinking of the farmers, with the expectations of the experts.

The answers to the 10 open-ended questions posed to the farmers were summarized regarding the system elements (Table 4) and subsequently grouped according to the corresponding livelihood capitals: human, health, natural and financial capital (Table 2). Additionally all farmers' statements were put in a system dynamic graph (Fig. 2) demonstrating the development from present to future of each capital of the system.

Concerning the answers gained in the experts' interview, an overview of the experts' development statements for each of the key system elements was constructed and listed (Table 8). Subsequently the statements were summarized in their corresponding capital groups (Table 2). Finally, experts' statements were also represented in a system dynamic graph (Fig. 2) demonstrating the development from present to future of each capital of the system.

Farmers' answers were analyzed in relation to experts' development expectations. This allowed the derivation of an opportunity-space showing what farmers wanted and what experts considered feasible or likely to happen by comparing both system dynamic graphs of farmers and experts.

Finally, the answers of the additional question concerning farmers' expectations for future education interventions were summarized separately as well as experts' plans for future education interventions.

3.3.3. Analysis part III

In part III of the interview the future agent networks of experts and farmers were analyzed. The farmers' future agent networks were analyzed according to the agents' distance from the farmer as shown in Fig. 3. Furthermore the experts' future agent network compared to the farmers' networks. The analysis was driven by the comparison of the agents' position in the agent networks of farmers and experts. The value of the agents' position was calculated as shown in Fig. 3 [36].

4. Results

In this section the main differences between farmers' and experts' future visions are presented. The results are again structured according to the three parts of the Future-SMMA interviews (Table 1). Part I shows the futures envisioned by farmers and the comments of experts. Parts II and III represent the future visions in the context of the livelihood capitals, of which part II encompasses the human, health, natural and financial capitals and part III the social capital.

4.1. Part I: definition and ranking of possible futures

4.1.1. Envisioned and desired future developments

Most of the farmers' future visions were related to four future scenarios prepared beforehand: cooperative, technical training, IPM and status quo (Table 7). Therefore the results of this part are presented directly in the frame of these four scenarios. Only two farmers envisioned a completely different future. One farmer dreamed of living outside the Vereda as a bus or truck driver in the nearby capitals, Tunja and Bogotá. Another farmer wanted to stay in the Vereda as the owner of a small shop or bakery.

Table 7
Ranking of farmers' and experts' future scenarios.

Ranking	Farmers (by preference)	Experts (by feasibility)
1	Cooperative	Technical training
2	Technical training	Cooperative
3	IPM	Status quo
4	Status quo	IPM

4.1.1.1. Cooperative.
4.1.1.1.1. Farmers' comments. For five farmers joining a cooperative is the most desirable future. Of these, only one farmer was actually a member of a cooperative, one was planning to join a cooperative and all the others had just heard about the possibility. Seven of the farmers were skeptical about the realization of a cooperative in the Vereda because they feared a lack of cooperation among themselves and a lack of mutual trust needed for engaging in such a (from their perspective) risky and dependence-increasing relationship. One farmer considered joining a cooperative the least desirable option for his future. For five farmers the gains of joining a cooperative were purely economic ones. Within a cooperative they could bypass intermediaries when selling potatoes or other crops and when buying pesticides and fertilizers. Two farmers hoped that by joining a cooperative they would obtain access to more sophisticated agricultural equipment.
4.1.1.1.2. Experts' comments. Even though experts agreed that creating a cooperative was the most desirable future, they were convinced that farmers were not sufficiently informed and that they could not conceive of all potential consequences of creating a cooperative.

4.1.1.2. Technical training.
4.1.1.2.1. Farmers' comments. Two farmers acknowledged that training and education in general was important to them. They furthermore stressed the importance of proper education as an investment for the future *also* via investing in their children's education. Still, only one farmer perceived the ongoing interventions and programs of governmental and

Table 8
Experts perceived constraints on key elements of farmers' future developments.

System elements (defined by SMMA interviews [36] and WS)	Best case	Intermediate condition	Worst case
Education	All children stay in school until end of 8th grade. Farmers attend schoolings	Status quo	Children leaving school; taking the children out of the schools
Tradition	Moderate loss of traditions	Status quo	Complete loss of traditions
Pesticide management	Improved use of pesticides	Moderate increase in pesticide use	Increase in pesticide use, increase in poisoning pesticides
House, family/Kitchen	Improvement due to SISBEN	Private investments	Status quo
Alimentation	More balanced food basket	Status quo	Deterioration because of changing markets
Soils	Moderate degradation (due to use of new conservation techniques)	Ongoing degradation of soils due to unchanged agricultural practices	High degradation of soils
Agricultural technology	Improve at a high rate (but just for major farmers)	Improve (if farmers become organized in a cooperative)	Status quo
Water	Solution of water rights, organized and controlled water use	Fight for water	No water left because of deforestation. Unfortunately highly connected to soil quality
Forest	Reforestation programs help	Moderate deforestation	Almost no forests
Livestock	Increase in livestock numbers. Better livestock genetic pool	Status quo	Need to sell livestock because of financial losses
Market	TLC helps the farmers. Demand for eco foods	No effects of TLC	TLC is bad for farmers. Small farmers vanish
Harvest	Improved quality due to "better" pesticides Change in harvest due to demand for biodiesel and ethanol	Status quo	More pests, more pesticide use

nongovernmental entities in the region as beneficial. All other farmers (9/10)[12] were somehow aware of training programs but complained of not learning enough from those programs in order to experience take-home, new and applicable, improving techniques for their day to day agricultural life.

4.1.1.2.2. Experts' comments. Experts commented that they had experienced farmers as being insufficiently engaged in the training programs offered to them. In particular, it seemed difficult and tiresome to reach farmers by organizing workshops and information campaigns. Still, according to the experts, education was the most important and most feasible element that should be improved in the near future.

4.1.1.3. IPM leading to less use/optimized use of pesticides or even to organic farming.

4.1.1.3.1. Farmers' comments. The issue of present and future pesticide use was the most controversially discussed and reflected the differences in mental models among the farmers. Four farmers explained that they could implement the principles of IPM; one of the four even stressed that completely refraining from using pesticides was the only way to a desirable future. In contrast, four farmers did not see a decreased use of pesticides in the region as feasible, two of the four stated that it was impossible to survive in their region and apply less pesticides. Those farmers explained that the environmental conditions in their region had already degenerated beyond the point of no return. Other farmers stressed lack of knowledge as the main obstacle for adopting new and more integrated techniques of agricultural cultivation. However, all farmers hoped that using pesticides less would help to improve their environmental conditions.

4.1.1.3.2. Experts' comments. Experts statements considered that a future applying less pesticide was not feasible from the farmers' point of view. They had experienced farmers as reluctant concerning IPM training and therefore had given up all hope for a change in that direction.

4.1.1.4. Status quo.

4.1.1.4.1. Farmers' comments. Nine farmers shared the opinion that maintaining the status quo would represent the least desired future. Five farmers stated that it was impossible to maintain the status quo as the region was in constant change and that this change would anyway lead to a better situation than the current one even if they did not make any additional efforts. Only one farmer ranked the status quo future in third position before the creation of a cooperative, which he placed in fourth position.

4.1.1.4.2. Experts' comments. Experts considered the status quo as a possible future. Considering the external changes that farmers will confront in the near future, they stated that the maintenance of the status quo would lead to a decline in farmers' living standard.

4.1.2. Ranking of four predefined optional futures

As presented in Binder and Schöell [35], the ranking of the previously defined future scenarios (Table 3) provide first insights into the differences in future visions between experts and farmers. For the Future-SMMA the ranking was adjusted such that farmers ranked the scenarios in order of preference while experts ranked them in order of feasibility.

As documented in Table 7, farmers preferred the *cooperative* scenario the most, and placed *technical training* second in their order of preference. In contrast, experts perceived the *technical training* scenario as the most feasible one (having their own training programs in mind, independent of other programs) and ranked the *cooperative* second in order of feasibility.

The ranking difference can be explained by the fact that experts ignored for the *technical training* scenario the point concerning coordination of trainings which farmers stressed by placing it in second position. On the other hand, farmers preferred to have a cooperative because of the financial reward promised for the establishment of a cooperative while ignoring all that would be needed to build up such a cooperative.

Furthermore farmers placed the *IPM* scenario third and the *status quo* scenario last in their order of preference. In contrast, experts perceived the *status quo* scenario as more feasible than the *IPM* scenario.

The difference in ranking can be explained by the differences in implications of the various scenarios. While farmers focused on the constant change perceived in their region, experts based their predictions on their experience that farmers were resistant to change. Concerning the *IPM* scenario, experts were pessimistic with respect to the farmers' ability to take up new farming technologies, while farmers stressed the urgent need for new solutions to reverse the observed deterioration of their environment.

4.2. Part II: system dynamic

4.2.1. Farmers' system dynamic statements

4.2.1.1. Future of human capital (expressed in: education, tradition). Farmers think that education will improve (see Fig. 4) in their desired future but they consider that to do so, the educational campaigns have to be better organized; that is, experts

[12] Nine of the ten interviewed farmers.

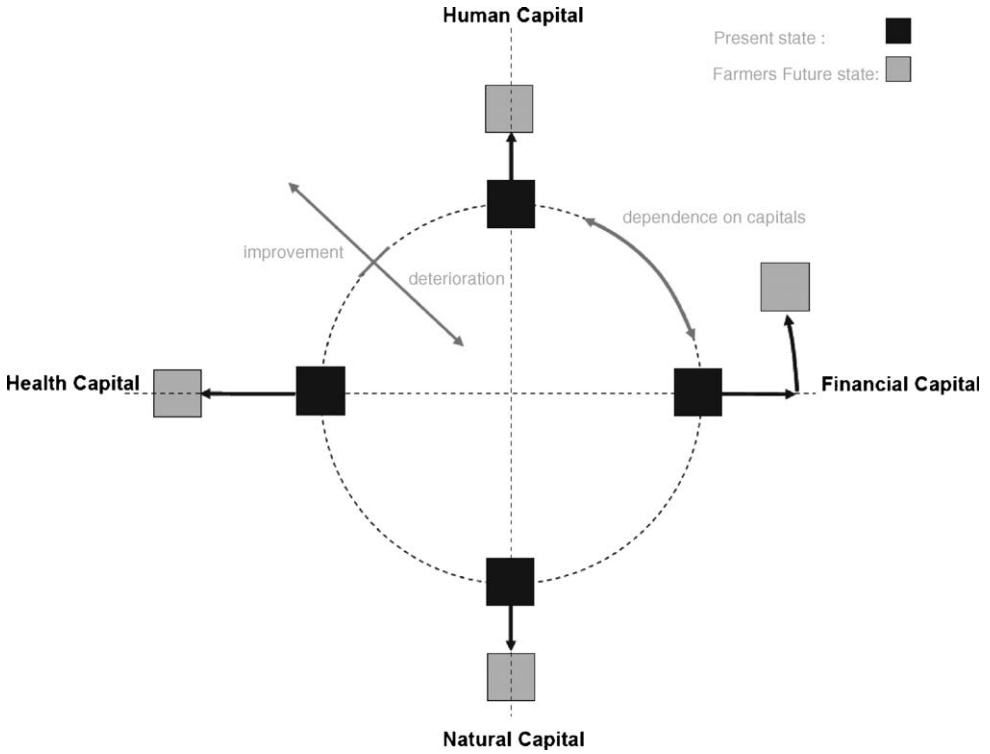

Fig. 4. Farmers' visions of the future capital states.

have to improve their training sessions. In addition, traditions concerning potato cultivation and pesticide application will and must change, but farmers could not state how.

4.2.1.2. Future of health capital (expressed in: house, alimentation, pesticide management). Farmers related their future health capital neither to an increasing or decreasing use of pesticides nor to the use of protective equipment. Instead, they were all convinced that in general they would have a better life. Especially with regard to alimentation and housing they believe they will be better off in the future.

4.2.1.3. Future of natural capital (expressed in: soil, water, forest, agricultural technology). In their desired future, farmers wish for better water and soil quality and less deforestation. In order to attain this future, farmers consider that better mechanization and better pesticides are necessary.

4.2.1.4. Future of financial capital (expressed in: livestock, market, harvest). Farmers envision that their future financial capital will be dominated by diversification of their production and further investments in animal husbandry. Furthermore, they fear effects related to the Trato del Libre Comercio (TLC)[13] and have contradictory expectations concerning the advantages and disadvantages of forming or entering a cooperative.

4.2.2. Future intervention plans

Farmers stressed that they were extremely interested in an increase in improved training sessions from CORPOCHIVOR and CORPOBOYACA, such as workshops or Farm Field Schools (FFS). Some (5/10) expressed their hope for increased educational support from the Servicio Nacional de Aprendizaje (SENA; Colombian National Learning Service) for starting and running a small business and/or a cooperative. Regarding the question of whom they would turn to in order to attain their future, two farmers named concrete options for government help, namely the mayor's office and the ministry of agriculture. In contrast, for one farmer governmental entities would be the last agent he would turn to.

4.2.3. Experts' system dynamic statements

4.2.3.1. Future of human capital (expressed in: education, tradition (Table 8)). The experts were convinced that farmers are increasingly investing in their education, especially in the education of their children, by keeping the children in the regional

[13] Free trade agreement with the United States of America.

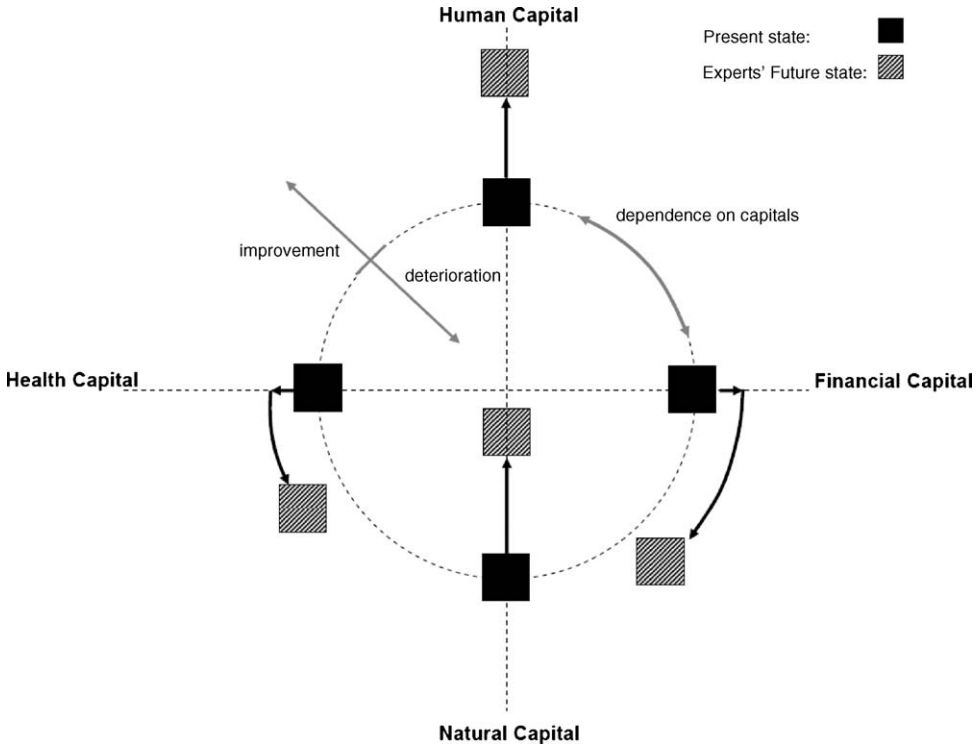

Fig. 5. Experts' visions of the future capital states.

school up to the 8th grade or even financing their further education in the nearby cities of Tunjá or Bogota. The interviewed experts and their corresponding organizations invest in farmers' education by adapting approaches like FFS to the topic of pest management, and sponsoring educational campaigns to foster the formation of cooperatives (Fig. 5). Experts also observed that farming traditions are fading away in the region.

4.2.3.2. Future of health capital (expressed in: house, alimentation, pesticide management (Table 8)). Experts expected the housing situation to improve as the campaigns of SISBEN (a Colombian social subsidy program) aimed at supporting farmers financially in constructing and renovating bathrooms, etc., in existing buildings have been successful. In contrast, experts do not expect alimentation and alimentation customs to improve. In their view this element reflects the influence of traditions and their maintenance. In particular, they consider that the daily diet consisting of mainly potatoes will remain the same for at least the next 10 years, independently of the changing market and changing availability of different foods. Concerning pesticide management, experts expect more toxic pesticides to appear on the local markets because they also expect more infestations to appear in this region. Experts were skeptical that farmers would improve their use of protection measures for applying pesticides.

4.2.3.3. Future of natural capital (expressed in: soil, water, forest, agricultural technology (Table 8)). Experts expect that natural resources will deteriorate further until 2017 and beyond. In their view the soil and water situation is not "bad enough" to change farmers' behavior concerning natural resource depletion. Experts had observed the failure of different reforestation campaigns (for example, those initiated by CORPOCHIVOR) and commented on them critically. They expressed the urgent need for further improvements in reforestation and reforestation regulations for the sake of water conservation, to avoid water scarcity in the region. Concerning agricultural technologies, experts stated that the technical assistance available was insufficient, and saw an increasing gap between small and big farmers in terms of mechanization. The only way for small farmers to increase their degree of mechanization would be to become organized in larger groups in order to buy equipment and share it among the group members.

4.2.3.4. Future of financial capital (expressed in: livestock, market, harvest (Table 8)). Concerning future markets and harvest it was impossible to derive a consensus statement from the experts' interviews. Some of the experts expect the TLC to bring improvements in the farmers' local markets by increasing the prices of the products or by making it possible to export special local potato varieties. Other experts feared that the farmers would not be appropriately prepared to confront new competitors on the local markets and that small farmers in particular had neither the means, the technical knowledge nor the financial support to become prepared. Some of the experts named the increasing demand for bio-diesel and ethanol a point

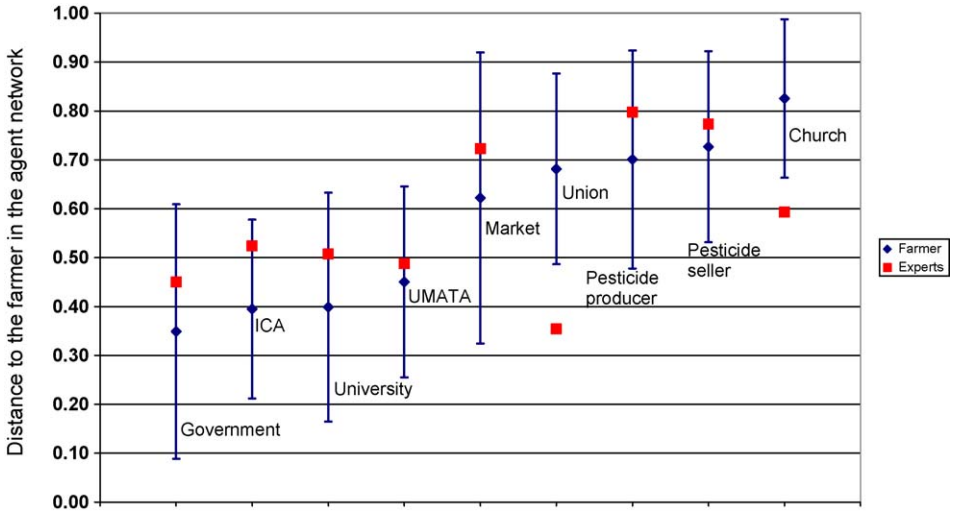

Fig. 6. Comparison of farmers' and experts' future agent network.

of concern which is likely to influence farmers by forcing them to change their main crops. In their opinion, livestock could improve as there are new and better breeds available on the market.

4.2.4. Future intervention plans

The interviewed experts named various planned future projects to improve the agricultural mechanization of farmers. All projects were planned for a time frame of maximum one production cycle and none of the projects was coordinated with one of the other technical assistance entities. Governmental efforts concentrate on building up cooperatives by giving financial support to newly formed cooperatives. Furthermore, the agricultural ministry of the region was currently working on a potato washing network in order to give added value to the product directly in the region before reselling it to super-regional and countrywide markets. Pesticide selling companies were concentrating on a recollection campaign for pesticide packages.

4.3. Part III: future agent networks

As shown in Binder and Schöell [35] the comparison of the two agent networks permits the distinction between means and potentials for interventions. The final experts' network was a straight line: Farmer-Farmers' Union–Government–UMATA–University[14]–ICA[15]–Church–Market–Pesticide seller–Pest producer (Fig. 6).

Fig. 6 illustrates the differences between the experts' and the farmers' network and includes only the standard deviation for the farmers' agent-networks according to the SMMA [35].

Compared to the farmers, the experts clearly overestimated the role of the farmers' union in the future-agent network. In contrast, farmers placed this agent in sixth position. This difference in the placement of the agent "union" resulted from farmers' negative experiences with their union in the last few years. While experts considered this agent to be the most important, for farmers "education" (educational agents), provided by the governmental agencies, the ICA the UMATA and the University, was of a higher importance and was perceived to be closer to them in the agent network. Furthermore, farmers stated that they should first be taught how to successfully manage a farmers' union and then how to form a cooperative.

Considering the agent church, again experts significantly overestimated its rank in the future agent network when compared to the farmers' statements. The experts placed the church in the same ranking-band with educational agents, since for them the church represented another source of information. For farmers the church was an element that did not directly influence their future as a partner, but rather spiritually, and thus they placed it last in the agent network.

The agents government,[16] ICA, UMATA and the university were consistently defined by farmers and experts as educational agents. Educational agents provide information on (i) how to build up a cooperative, (ii) how to improve agricultural techniques (ICA and UMATA) and (iii) how to deal with possible crop losses. Again the first position of the government in farmers' future agent network was strongly influenced by recent events in the study area, where the farmers had just lost part of their harvest due to frosts and hoped for financial compensation from the government. Similarly to the

[14] The element "university" was just added to allow the farmers to place the interviewers somewhere in the system. Results concerning this agent will not be discussed further.

[15] ICA Instituto Colombiano Agropecuario (Colombian Agronomy Institute).

[16] Even though the ICA and the UMATA are also governmental entities, farmers did not relate them to the government.

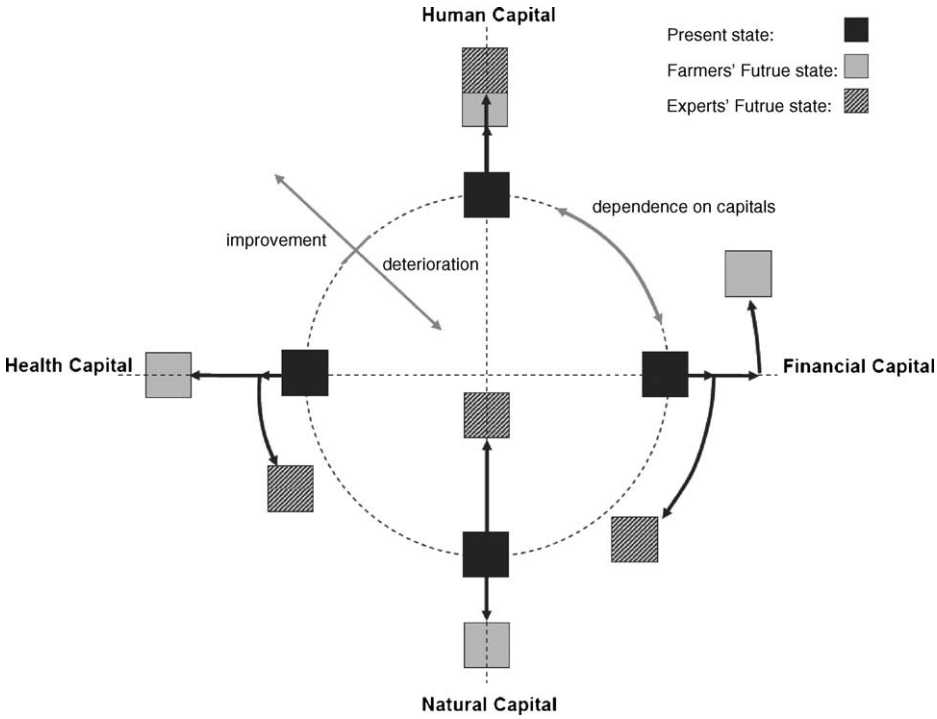

Fig. 7. Comparison of farmers' and experts' visions of the future capital states.

farmers' perception, experts placed these "educational-agents" close to the farmers, stating that they were of high importance in achieving the farmers' desired future.

Concerning pesticide producers and sellers, experts placed pesticide sellers closer to the farmer in the network, whereas farmers placed pesticide producers closer. Farmers argued that when they had agreed on a farmers' cooperative, it would be easier to receive discounts on pesticides by negotiating directly with producers.

In line with the previous findings [36], the market, representing customers and intermediaries, was seen by the experts as an element on which farmers will depend in the future, whereas farmers seem to perceive that they will be able to influence local prices once they have formed a cooperative.

Additional agents named by the farmers were the bank (very important for obtaining credit in the future) and CORPOCHIVOR (a new agent in the network that provides training in the conservation of the water ponds).

5. Discussion and conclusion

In the following, we first summarize our research findings and discuss two important aspects of the findings and their consequences for farmers' future; subsequently we present strengths and weaknesses of the Future-SMMA and, finally, propose ideas for further research.

5.1. Research findings

We applied the method of Future-SMMA to investigate farmers' futures with reference to the pesticide management of potato growing farmers in Vereda la Hoya (Boyacá, Colombia). In so doing we investigated farmers' future visions and found that farmers consider social and environmental threats and that their visions are optimistic. We compared farmers' and experts' perceptions of external constraints on farmers' future and discovered that the investigated future visions of farmers and experts were inconsistent (Fig. 7). In addition, experts are worried that farmers do not sufficiently consider external constraints. Finally, we determined how farmers' livelihood assets and self-perception influence the formulation of farmers' future visions and found that the more a farmer was able to differentiate his livelihood assets, the more differentiated were his future visions.

In the following we discuss how the inconsistency of future visions found is due to diverging attitudes[17] towards future scenarios and differing opinions about who should take responsibility for the knowledge management of farmers. These two aspects have to be considered in the successful design of agricultural development plans [52].

[17] Farmers and experts had diverging attitudes *in general towards the future* and especially concerning *shifting to integrated farming*. In addition farmers and experts showed differing interpretations concerning *the formation of cooperatives*.

5.1.1. Diverging attitudes

The farmers demonstrated in their statements that they had a more optimistic attitude towards the future than did the experts. Similar findings concerning levels of optimism toward the future were found in other future studies presenting several explanatory factors [28,29,53].

First, interviewed experts were older than farmers, which could explain part of the found deviation in attitude. Concerning optimism and pessimism Hicks [53] found that in relation to personal future, optimism decreases with age. Likewise Chenoweth et al. [29] found in his study that older students were less optimistic than younger ones.

Second the fact that experts were asked to talk about the future of farmers and not their own could also explain why experts attitude was more pessimistic. For example Hicks [54] found that the pupils participating in his study were generally more optimistic about their own future then about the local or global future.

Third farmers' positive attitude towards the future could be explained by farmers having a less realistic attitude towards the future. That is experts visions were found to be more pessimistic because they were more realistic and farmers' visions were found to be more optimistic because they were more idealistic. Similar to that are Rubin's findings comparing the Future Image Index Map of teachers and adolescents [28].

Moreover other findings demonstrate that professionals tend to show more cautious and reserved expectations towards the future than laymen [26,55]. Furthermore, even within the farmers' group we found that the more a farmer was able to relate causes and effects within the livelihood-system, the more differentiated was his attitude towards the future and the less optimistic were his future visions. Hence, these results provide further evidence for a relation between the extent of rational reasoning and attitude towards the future.

The following example illustrates more clearly the critical implications of these diverging attitudes for the development of agriculture techniques. Farmers were interested in reducing the use of pesticides and therefore showed their readiness to implement ideas of IPM. In contrast, experts were more negative towards the feasibility of farmers adopting IPM. This attitude divergence leads to the unwillingness of experts to listen to farmers' demands and hinders a constructive development process. These findings are comparable to those of Wheeler [17] and a survey of organic farmers in the US [56], which reported that the greatest constraints on the conversion to organic farming are uncooperative or uninformed extension officers.

In a similar vein our findings showed that farmers and experts have a different understanding of what the scenario cooperative would imply for the farmers' future. Farmers perceived the advantages of being a member of a cooperative while focusing on financial benefits especially in unfavorable market conditions. However, they were dismissive of any dependence and commitment within a cooperative, given the bad experiences they had had with the farmers' union. In contrast, experts ranked the union (as a predecessor to a cooperative) as the most important agent in the farmers' future agent network, thereby ignoring farmers' negative experiences with their union. Hence farmers' and experts' differing attitudes toward commitment in a cooperative exemplify a critical hindrance to progress in agricultural development.

5.1.2. Ambiguities in responsibility assignments

Our results also demonstrate different opinions about who should take responsibility for the knowledge management of farmers. This disagreement is also likely to hinder the development of agriculture in the region and is illustrated by the following examples.

Technical advisers in the region contracted by governmental or nongovernmental entities were not coordinating their educational interventions. In addition, farmers were increasingly unmotivated to attend several extension programs because they had received contradictory information from different programs. Nevertheless, farmers were convinced that improved and coordinated agricultural support (providing more information concerning agricultural techniques in general and pesticide application in particular) would be crucial for them in attaining their desired future. Hence, farmers place the responsibility for their knowledge in experts' hands. This "perspective" is in line with other research findings concerning farmers' knowledge sources [57,58]. In contrast, experts were convinced that farmers should first be more receptive to new information provided by educational staff before educational efforts could be adjusted to farmers' demands. Therefore experts see farmers themselves as being responsible for their knowledge management. Similar observations were made by studies focusing on the adoption of organic farming [59].

The experts who first take responsibility for coordinating farmers' training will be the ones farmers will then depend on. This statement reveals the danger of the increasing dependency of farmers on external experts and offers the opportunity to change farmers' future. As shown in the agent network and previous findings in the study region [36], pesticide selling companies currently seem the most willing to fill this responsibility gap. Another point of concern is that if farmers have to pay for their technical advisors, taking responsibility for their knowledge themselves, richer farmers, who can afford to pay for professional technical advice, will be favored over poorer farmers, thus increasing the gap between the two.

5.2. Strengths and limitations of the Future-SMMA

When analyzing the interpretive horizon concerning future perspectives, it should be kept in mind that investigating the future opens up a much broader view of a system than investigating the present. First because (as in perceptions of the present) the perceptions of the future are as different as the people perceiving it, and second, each of these different perceptions again contains a variety of different future expectations [26]. However, the tools and structure of the Future-

SMMA have been shown to cope with these challenges of future research by focusing on key system elements and thereby enabling us to compare them and to deduce useful and traceable conclusions for the farmers' future.

During the farmers' interview a drop-off of new concepts was observed after 4–5 farmer interviews. When the characteristic drop off of new concepts is encountered after 5 interviews, the sample size of 10 persons is sufficient, according to Maharik et al. [51], to get a first impression of the existing mental models. Still, the relatively small number of interviews conducted constitutes a shortcoming in the validity of the Future-SMMA and the conclusions drawn from its results. The results should therefore be validated with a survey as suggested by Morgan et al. [38] which would show the proportion of the future visions and influences of livelihood assets on future visions present in the population. Furthermore statistical analyses of the survey results could be conducted to investigate possible reasons of diverging attitudes like age, level of optimism of own and local futures, and level of realism.

5.3. Further research

The Future-SMMA applied here is a first step in identifying farmers' future visions and how they are influenced. Departing from our findings, the next step would be to develop a common understanding of the future among farmers and experts and to assign responsibilities by performing a commonly agreed backward planning, for example by arranging a future scenario workshop.

In addition, to confirm the influence of livelihood assets on future visions an analysis of the cause-and-effect thinking of farmers, as suggested by Mackay and McKiernan [26], would be important and could be performed by comparing results of the Future-SMMA with the results of the SMMA applied previously in the study region.

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Paper 4

Comparison of Farmers' Mental Models of the Present and the Future: A case study of pesticide use

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Comparison of farmers' mental models of the present and the future: A case study of pesticide use

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ABSTRACT

Farmers in developing countries will in the future be confronted with major changes. The ability to cope with these challenges rests on their capability to relate future problems to current behavior. Our approach investigates this capability and consists in comparing mental models of the present and future. The approach moreover enables us to explore whether and how farmers are able to imagine a future differing from the perceived present.

Data from previous studies investigating present and future pesticide application were used. In the datasets the mental models of farmers' livelihood were structured into livelihood capitals (human, health, natural and financial capital), causal relations among the livelihood capitals were derived, and present and future causal relations were compared.

The comparison of these causal relations led to six cases, each representing a different degree of dependence of future on present causal relations. The dependence was found to vary among farmers and analyzed livelihood capital. Three types of farmers with differing dependence patterns were identified.

The differences found lead to new insights for policy recommendations, depending on farmers focus in their causal relations. We therefore expect that interventions focusing either more on the causes or effects of causal relations will result in a better uptake of knowledge by farmers.

1. Introduction

It is becoming clear that in the future farmers in developing countries will be confronted with major changes. First, changing climate might lead to changes in the length of summer and winter seasons, with consequences for agricultural production [1]. Second, the spread of pests throughout the world due to increased trade might lead to yield losses [2]. Third, changing agricultural markets reshaped by the demand for organic food, bio fuels and genetically modified plants might change the applied agricultural techniques and input costs of farmers [2,3]. It is a matter of debate whether and how farmers will be able to adapt to these future challenges, and, whether they are aware of these future changes.

Farmers envision their future, among other factors, based on their mental models of the present and future [4,5]. Depending on the accuracy and flexibility of these mental models, farmers can be more or less prepared for changing future conditions. Furthermore, depending on their accuracy, they can either imagine the need for new measures or will rely on established measures to deal with upcoming changes. For example, pesticide application in less developed countries is increasingly related to health and environmental risks [6]. Farmers have to decide if, which, how and how much of the pesticides to apply and if and how they want to protect themselves while applying the pesticides. The neglect of protective

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equipment and the overdosage of pesticides, as examples on how farmers coped with a change in their agricultural techniques, represent therefore farmers' errors of behavior possibly related to misapprehensions in farmers' mental models. Thus, we investigate the present- and future-oriented mental models of farmers observed to apply pesticide unreasonably and compare them. In this, the study tries to relate unreasonable pesticide use and handling to misapprehensions found by comparing mental models of the present and future.

Throughout the entire publication we use the expressions "mental models of the present and the future" and "present and future mental models" as synonyms, meaning with both expressions mental models of present and future situations. For mental model we use the abbreviation MM.

1.1. Dependence of future mental models on present mental models

The influence of past and present MMs on the construction of future MMs has been analyzed and critically discussed by different researchers in the field of future studies [7–11]. For example Bell and Mau's Cybernetic-Decisional Model of Social Change [8] explains the time aspect of future MMs by stating that beliefs about the present contribute to the formation of MMs of the future. They state that MMs of the future are dependent on the MMs of the present. Furthermore, MacKay and McKiernan [9], in analyzing the role of hindsight in foresight, discusses cognitive linkages between present and future and lays special emphasis on how foresight biases are formed and influence future MMs. Blackman and Henderson [4], in analyzing the influence of present on future images, argues that foresight can be defined as being MMs about the future. She states: "foresight is merely a picture, a MM to guide decisions and actions operating between the present and the expected future state. The efficiency of the foresight depends on both the accuracy of the MM and the consistency of the actions with it." Additionally, Ono [11] found in his studies comparing students from Taiwan and the US that young people see the past and the present, about which they have some knowledge, extrapolate them into the future, and thus form a MM of the future.

All these examples demonstrate that past and present MMs have an impact on future MMs. However, they do not describe the actual mechanism of dependence. Moreover they are general in nature and none of them compares the MMs of a specific problem in the present and the future. We claim that mechanism of dependence of future on present MMs can be shown by starting from a similarity analysis of present and future MMs of a specific problem, such as pesticide use.

1.2. Factors of prediction going beyond the theory of explanation

Most of the studies considering the comparison of present and future MMs have been performed in behavioral neuroscience [12] not in future studies. One reason could be the ongoing discussion about the epistemological basis for comparing explanation (used in MMs of the present) and prediction (used in MMs of the future). Some research schools state that explanation and prediction are identical [13], others, that they are not [14]. The theory of Logical Positivism postulates that explaining and predicting events are logically identical. The classical statement of logical symmetry of explanation and prediction is Hempel's "covering law" [13,15]. Reasoning about matters of fact is, as Hume says, largely based on causal relations [16]. According to Goldvarg and Johnson-Laird [17] causal relations (cause and effect[1]) allow the inference of what will happen such that investigating causal relations in MMs may reveal what is inferred from present MMs to predict the future and to construct MMs of the future.

In contrast to Hempel [13], Aligica [14] states in his work that in future-oriented intelligence, the tacit personal and social dimension of background knowledge play an important role. Therefore, comparing explanation and prediction should consider the intrinsic social nature of knowledge and knowledge production. Additionally, Aligica [14] is aware that the epistemology of future studies cannot be reduced to a mere extension of a theory of prediction. Themes such as conditionals, counterfactuals and scenario-related analytical narratives carry their own epistemological load, and are as important as prediction [18]. Thus by comparing the symmetries of causal relations of present and future MMs the influence of tacit personal and background knowledge on future MMs may me measured.

To summarize, only a few studies have actually compared MMs of the present with MMs of the future, even though comparing present and future causal relations may provide a measure of accuracy of MMs or help to further understand the epistemological particularities of future MMs. Hence the goal of this paper is to fill this research gap by investigating the following research questions. In this the case study of pesticide use in Vereda la Hoya (Colombia) provides the applied context:

(I) How can MMs of the present and future be compared systematically?
(II) How dependent are future MMs on present MMs?
(III) For the case study of pesticide application: How do farmers' present and future MMs differ considering different livelihood capitals?
(IV) How do present and future MMs of farmers' pesticide application differ from farmer to farmer?

[1] Causality denotes a necessary relationship between one event (called cause) and another event (called effect) which is the direct consequence (result) of the first.[Random House Unabridged Dictionary].

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The structure of this paper is as follows. This section is followed by a Section 2 showing how farmers' present and future MMs were compared, followed by a section introducing the interview subjects. Subsequently, the results of the comparison are presented. Finally, in a Section 5, the results found are summarized and the consequences of these results for policy recommendations concerning pesticide application are explored.

2. Methods

2.1. Conceptual model for comparing causal relations of the present and future

According to Brunswicks' [19] cognition theory it is not possible to perceive an object or an event directly. It is only possible to construct internal representations of real objects and events from sensory information. These internal representations then form the basis for conclusions [19]. A MM is the sum of the internal representations; it is a model of someone's reasoning about how something works in the real world [20]. Reasoning in the form of MMs is largely based on causal relations [16,21,22], and these causal relations are important elements in MMs, allowing people to infer what will happen [17].

Causal relations can be formulated in a reflexive form. This means that they can be formulated either by stating that a certain cause is expected to generate a certain effect (cause 1 ⇨ effect 1), or they can be formulated by stating that a certain effect is provoked by a certain cause (effect 1 ⇦ cause 1). The two formulations are mirrored arguments and therefore equivalent in their meaning. Present and future MMs contain either identical causal relations or mirrored versions of the identical causal relations. In Table 1 the possible causal relations statements and their reflexive formulation appearing in present and future MMs are shown and illustrated by an example.

The comparison of present and future MMs can therefore occur in several ways, either by comparing a causal relation, or the reflexive form of that causal relation, in present MMs with the equivalent causal relation in future MMs. Either way, by comparing causal relations of present and future MMs it is possible to determine whether equivalent causes and effects in the two MMs are identical or not. Investigating causal relations in MMs may reveal what is inferred from present MMs to predict the future. Moreover any symmetries found suggest that an inference from a present MM is actively used to construct future causal relations showing a dependence of the future MM on the present MM.

Causal relations can also differ and there are two explanations for why they might do so. First, causal relations in present and future MMs differ due to the fact that they may change in the future. Farmers who are aware of changes in the future, have future MMs which are less dependent on present MMs. Such farmers may have competitive advantages concerning future developments (Table 2 case *). In this case differences in the cause or effect of causal relations provide a measure of what farmers expect to change in the future, or what else, in the farmers' opinion, has to change in order to reach a certain desired future. For example in the case study of pesticide use, if farmers hope that pesticides will become less toxic in the future, they may tend to care less about protection equipment in the present.

Second, causal relations in present and future MMs differ due to the fact that the causal relation is not properly understood. In this case, only one of the two relations either in the present MM or in the future MM is correct (see Table 2

Table 1
Causal relations and their reflexive form in present and future MMs.

	Present MM (consisting of explanations)		Future MM (consisting of predictions)	
Causal relation	The unprotected use of pesticides leads to nausea and headache. Cause 1 ⇨ effect 1		In the future the unprotected use of pesticides will lead to nausea and headache. Cause 1 ⇨ effect 1	
	Cause 1:	Application of pesticides without use of protection equipment	Cause 1:	Application of pesticides without use of protection equipment
	Effect 1:	Nausea and headache	Effect 1:	Nausea and headache
Reflexive form of causal relation	Feeling nausea and headache while or after applying pesticides in the field is caused by omitting the use of protection equipment. Effect 1 ⇦ cause 1		In the future, feeling nausea and headache while or after applying pesticides in the field will be caused by omitting the use of protection equipment. Effect 1 ⇦ cause 1	
	Cause 1:	Application of pesticides without use of protection equipment	Cause 1:	Application of pesticides without use of protection equipment
	Effect 1:	Nausea and headache	Effect 1:	Nausea and headache

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Table 2
Differing causal relations in present and future mental models.

	Present MM (consisting of explanations)		Future MM (consisting of predictions)	
			Changed effect in the future influencing causal relation: In the future pesticides will be less toxic and the use of protection equipment will not be necessary anymore.	
Causal relation	The unprotected use of pesticides leads to nausea and headache. Cause 1 ⇨ effect 1		In the future the unprotected use of pesticides will not lead to nausea and headache. Cause 1 ⇏ effect 1*	
	Cause 1:	Application of pesticides without use of protection equipment	Cause 1:	Application of pesticides without use of protection equipment
	Effect 1:	Nausea and headache	Effect 1:	Nausea and headache
Reflexive form of causal relation	Feeling nausea and headache during or after applying pesticides in the field is caused by working in the sun for a long time. Effect 1 ⇦ cause 2		In the future feeling nausea and headache during or after applying pesticides in the field will not be caused by omitting the use of protection equipment. Effect 1 ⇏ cause 1*	
	Cause 2:	Long working hours in the sun	Cause 1:	Application of pesticides without use of protection equipment
	Effect 1:	Nausea and headache	Effect 1:	Nausea and headache
			In the future feeling nausea and headache during or after applying pesticides in the field will be caused by working in the sun for a long time. Effect 1 ⇦ cause 2**	
			Cause 1:	Long working hours in the sun
			Effect 1:	nausea and headache

*The compared causal relation is identical in present and future MMs, identical cause and effect are mentioned in the MM, thus the future MM depends on the present MM even though the effect does not hold anymore. **The causal relations of present and future MMs differ and therefore indicate less dependency of the future MM on the present MM. The loss in dependency may either be due to misapprehensions or due to expected changes in causal relations in the future.

case **). That is, the comparison reveals misapprehensions in farmers' MMs and therefore a low accuracy of the MMs. Such misapprehensions in the case of pesticide application enhance understanding as to why farmers do not apply pesticides properly.

On a more concrete level, to obtain causal relations comparable to those presented in Table 1, the questions posed to the interviewee have to be posed so as to cover cause and effect, asking once about the cause and once about the effect, so that they can be organized comparably to the scheme in Table 1. The possible questions to be asked are illustrated in Table 3. Each question in the present has a corresponding question in the future. Each question referring to a specific cause has a corresponding question referring to the effect found in the reflexive form.

2.2. Database for comparing and classifying statements

In order to compare present and future MMs both types had to be collected from the same subjects and had to deal with the same specific topic, in this case handling of pesticides, suitable for explanation and prediction. The specific topic chosen in this research is the handling of pesticides. The dataset was gathered from potato producing farmers making decisions about if and how to use pesticides for agricultural production now and in the near future. The data were collected by applying the Structured Mental Model Approach (SMMA) [23,24] and the Future Structured Mental Model Approach (Future-SMMA) [25].

The SMMA [23,24] is used to elicit the present MMs of farmers in the context of their livelihood by means of an interview structured into three parts: part I definition and weighting of the different livelihood capitals; part II analysis of livelihood dynamics; and part III definition of the social capital (see Table 4 left). The SMMA is a tool combining the Mental Models Approach (MMA) [26] and the Sustainable Livelihood Framework (SLF) [27]. The approach was first applied in the context of pesticide application [23] in order to determine MMs of farmers and experts explaining the reasoning behind farmers' present pesticide use.

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Table 3
Possible questions concerning human capital posed to pursue specific causal relations.

	Present MM (consisting of explanations)		Future MM (consisting of predictions)	
Question	What do you do if the harvest is affected by pests and climatic conditions? Cause 1 ⇨ effect 1		What would you do in the desired future if the harvest is affected by pests and climatic conditions? Cause 1 ⇨ effect 1	
	Cause 1:	Harvest affected by pests	Cause 1:	Harvest affected by pests
	Effect 1:	?	Effect 1:	?
Reflexive question	When do you see yourself forced to apply more pesticides? Effect 1 ⇦ cause 1		Why would you apply more pesticides in the desired future? Effect 1 ⇦ cause 1	
	Cause 1:	?	Cause 1:	?
	Effect 1:	Use pesticides with higher frequency to protect the crop	Effect 1:	Use pesticides with higher frequency to protect the crop
Question	Does the use of pesticide have additional side effects? Cause 1 ⇨ effect 1		Will the use of pesticides have additional side effects in the future? Cause 1 ⇨ effect 1	
	Cause 1:	Use of pesticides	Cause 1:	Use of pesticides
	Effect 1:	?	Effect 1:	?
Reflexive question	Have you noticed a change concerning pest incidence? Why do you think is this so? Effect 1 ⇦ cause 1		Will you expect a change concerning pest incidence in the future? Why would you do so? Effect 1 ⇦ cause 1	
	Cause 1:	?	Cause 1:	?
	Effect 1:	Change in pest incidence	Effect 1:	Change in pest incidence

Table 4
Overview of SMMA and Future-SMMA.

Method	Focused timeframe [execution year]	
	Present [2005]	Future [2007]
	SMMA	Future-SMMA
Aim	Farmers' model of their livelihood	Farmers' model of their desired future livelihood
Part I	Grouping of the elements into four capitals (human, health, natural and financial capital) Weighting of the capitals	Formulating a desired future Ranking of the futures
Part II	Answering open-ended questions about the relations between the capital groups	Answering open-ended questions about the relations between the capital groups regarding farmers' desired future
Part III	Designing an agent network	Designing future agent network on the basis of first network (2005) and depicting the constraints
# Participants	10	7[a] + 3

[a] Previously participated in the SMMA.

The Future-SMMA [25] is used to elicit the future MMs of farmers and translates the three parts of the SMMA (see Table 4 right) into a future perspective. The first application of the Future-SMMA investigated farmers' future MMs of pesticide application.[2]

A review of results obtained from the three parts of the SMMA and Future-SMMA did reveal classifiable causal relation statements only for part II. Thus, in the following, we will present the comparison of farmers' statements originating from part II and only refer to parts I and III and experts' statements where necessary.

In part II of the SMMA and the Future-SMMA questions were posed to understand how farmers view specific causal effects in the present and the future the statements that first came to the subject's mind were written down. The subjects used either identical causal relations in present and future or a reflexive form of the identical causal relation, or else a different cause or effect in explaining the phenomenon. In the SMMA the subjects were usually asked what effect they expected with respect to a specific cause (cause ⇨ effect) (i.e. a possible cause is "pest incidence in the field" and the concluded effect is "use of pesticides"). In contrast, in the Future-SMMA the subjects were usually asked with respect to a specific desired effect what cause they would presume to lead to that effect (effect ⇦ cause) (i.e. "use of less pesticides" is caused by "less pest incidence

[2] For further detail about the SMMA and the Future-SMMA method see the corresponding publications [21–23].

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Table 5
Overview of different characteristics of the farmers compared via SMMA and Future-SMMA.

Farmer	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7
Year of birth	1969	1981	1974	1965	1967	1969	1979
Human (1–5)[a]	5	3	3	2	4	3	1
Natural (1–5)[a]	5	2	3	4	5	1	2
Financial (1–5)[a]	5	2	2	3	5	3	1
Social (1–5)[a]	4	3	4	3	5	2	1
# of comparable statements	46	42	44	38	44	40	40

[a] 1 = low capital state; 5 = high capital state.

in the field") (see corresponding publications for further examples of the questions posed during the part II of the SMMA [23] and Future-SMMA [25]).

2.3. Classification scheme

The causes and effects determined with the SMMA were compared with those obtained with the Future-SMMA. The cause-effect statements sequences were turned to its reflexive form if necessary in order to fit into the classification scheme. Furthermore, negative causal relations were compared to positive ones. This means that, e.g., the causal relation "... high potato quality leads to high prices for potatoes ..." in the present MM was compared to the causal relation "... there will be a decrease in potato quality leading to a decrease of the prices for potatoes ..." in the future MM. In this case the two causal relations were seen to be equivalent, as cause and effect were equivalent because both were either positive or negative.

A classification scheme of six cases (cases 1–6) was developed according to the differences of causal relations between present and future MMs. Each of the six cases represented a different level of dependency of the future on the present MM. All comparable causal relations were then classified into one of the six cases. The classification scheme derived, constitutes the first results of the research.

As a final step, in order to obtain a measure for the dependency between present and future MMs among first the different capitals and second farmers interviewed, the frequency of a certain cause and effect pattern (in other words the occurrence of a case) was calculated. For the first frequency calculation, all compared causal relations for each individual capital (human, health, natural and financial capital) were classified into one of the six cases and the occurrence of each case was calculated. From the frequencies of the different cause and effect patterns the corresponding dependency of future statements on present statements of each capital was derived. For the second frequency calculation, all compared statements of each farmer's present and future MM were classified into one of the cases. Analogously to the analysis of the capitals, the frequencies of the different cause and effect patterns were calculated for each farmer. From the different frequencies obtained, the dependency of future on present statements for each farmer could be concluded. Similar patterns of dependency of future on present statements were summarized and three different farmer types were obtained.

3. Interviewed subjects

In the study region Vereda la Hoya located in the rural part of Tunja (Colombia) potato farming with extensive use of pesticides represents the main source of income [23,25]. In Vereda la Hoya 10 farmers were interviewed with the SMMA [23] and 10 farmers were interviewed with the Future-SMMA [25]. Seven of the farmers participated in both studies, thus the data of those seven could be used for the comparative study. The farmers were chosen by purposeful sampling and qualitative differences in their individual and social capitals (Table 5).[3]

4. Results

4.1. Classification scheme of causal relations

Table 6 shows the six cases found by comparing causal relations originating from present and future MMs.

In case 1 cause and effect were identical in the compared causal relations of present and future MMs. Farmers giving the identical causal relation in present and future MMs used the present causal relation to predict the future (Table 6). In case 2 the causal relations differed in that an additional cause was added to the statement in the future causal relation. These farmers used a present causal relation to predict the future but imagined an additional cause in the future. In case 3 the causal relations differed by cause. That is, farmers imagined another cause than the one they had experienced in the present to lead to the identical effect. In case 4 the causal relations differed by an additional effect imagined by the farmer in the future. In case 5 causal relations differed by effect. That is, farmers imagined another effect to result from a cause identical to

[3] For further details on the selection of farmers see the corresponding publications [21,23].

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Table 6
Possible cases of compared cause and effect statements.

Case	Present (from SMMA)	Future (from Future-SMMA)	Comparison of present and future statements	Symmetry type	Derived dependence of future on present MM
1	Cause 1⇨effect 1	Effect 1⇦cause 1	Identical	Completely symmetrical	Completely dependent
2	Cause 1⇨effect 1	Effect 1⇦cause 1 + 2	Different in several causes	Asymmetric with additional cause	Partly dependent but needs additional cause
3	Cause 1⇨effect 1	Effect 1⇦cause 2	Different in cause	Asymmetric by cause	Dependent by effect
4	Cause 1⇨effect 1	Effect 1 + 2⇦cause 1	Different in several effects	Asymmetric with additional effect	Partly dependent but needs additional effect
5	Cause 1⇨effect 1	Effect 2⇦cause 1	Different in effect	Asymmetric by effect	Dependent by cause
6	Cause 1⇨effect 1	Effect 2⇦cause 2	Different in cause and effect	Completly asymmetric	Independent

Table 7
Overview of case frequencies per capital.

Investigated capital [# of compared statements]	Human capital [98]	Health capital [42]	Natural capital [84]	Financial capital [42]
Case 1 (completely dependent)	54%	32%	70%	48%
Case 2 (independent by additional cause)	3%	5%	9%	9%
Case 3 (independent by cause)	20%	26%	12%	19%
Case 4 (independent by additional effect)	3%	0%	2%	0%
Case 5 (independent by effect)	11%	32%	5%	19%
Case 6 (completely independent)	9%	5%	2%	5%
Sum	100%	100%	100%	100%

Table 8
Overview of case frequencies per farmer.

Case\farmer	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7
Case 1	61%	67%	55%	32%	54%	50%	45%
Case 2	0%	5%	4%	0%	9%	15%	0%
Case 3	22%	9%	18%	37%	14%	20%	20%
Case 4	0%	0%	0%	5%	9%	0%	0%
Case 5	13%	14%	14%	16%	14%	5%	25%
Case 6	4%	5%	9%	10%	0%	10%	10%
Sum	100%	100%	100%	100%	100%	100%	100%

the one they had experienced in the present. Finally, in case 6 all statements referring to the equivalent causal relations in present and future MMs were compared and no comparable causes and effects could be found.

4.2. Different frequencies of cases in different capitals on aggregate level

Table 7 gives an overview of the compared statements summarized according to the four individual capitals of the system (human, health, natural and financial capital). A total of 266 statements were compared (98 concerning human capital, 42 concerning health, 42 concerning financial capital and 84 concerning natural capital); thus 133 pairs of cause and effect where classified into the six defined cases.

Overall natural capital with 70% of the statements falling into the case 1 category, showed the strongest dependence of future on present statements among all livelihood capitals. Human and financial capitals were second and third respectively in frequency of case 1 statements. Health capital had the lowest frequency of case 1 statements and therefore the lowest dependency of future on present statements.

4.3. Different frequency of cases on individual level

Table 8 gives an overview of the frequencies in cases of the compared statements summarized on an individual level, i.e. by farmer.

With respect to frequency of different cases, three types of farmers were found (Table 9).

4.3.1. Type 1 farmer: the deductive effect-focused farmer

For all type 1 farmers, case 1 was highest in occurrence; moreover type 1 farmers produced more case 3 than case 5 statements. That is, for the majority of the statements, these farmers showed a complete dependence of future on present statements. In other words, the deductive effect-focused farmer is classified as expecting either the identical causal relation in the future, or just effects equivalent to those he experiences in the present.

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Table 9
Overview of farmer types.

Farmer type	Compared frequency of cases	Name
1	Case 1 > case 3 > case 5	The deductive effect-focused farmer
2	Case 1 > case 5 > case 3	The deductive cause-focused farmer
3	Case 3 > case 1	The imaginative effect-focused farmer

4.3.2. Type 2 farmer: the deductive cause-focused farmer

For all type 2 farmers, case 1 was also highest in occurrence, but in contrast to type 1, the type 2 farmers gave more case 5 than case 3 statements. In other words, these farmers mentioned more differences in effect (case 5) than cause (case 3). This type of farmer appeared to expect an unknown effect of a cause he experienced in the present. Thus, the farmer demonstrated his belief that effects may change in the future and that causes can still lead to the desired effects under different circumstances.

4.3.3. Type 3 farmer: the imaginative effect-focused farmer

This type of farmer made more case 3 than case 1 statements, producing fewer dependency of future on present statements than all other farmers. This means that the probability that he will relate his present behavior to the chance of achieving a desired future is lower than for a farmer with more case 1 statements.

5. Discussion

This paper constitutes a first attempt to compare present explanations and future prediction, in order to elicit the dependence of future on present MMs. It thus serves as a basis for future studies and indicates how further investigations may be structured.

5.1. Research findings

From the viewpoint of the research questions posed in this study, the following findings were revealed:

(I) It was possible to compare present and future MMs by comparing causal relations. Moreover the comparison led to the derivation of six cases of differing causal relations.
(II) The differences between the present and future MMs indicated dependencies and independencies of future on present MMs by cause, effect or both.
(III) For the case study of pesticide application the dependencies differed by type of capital analyzed: natural capital with 70% of the statements falling into the case 1 category showed the strongest dependency of future on present statements, while human capital showed 54%, financial capital 48%, and health capital 32%.
(IV) For the case study of pesticide application the dependencies differed among the farmers. Three types of farmers were defined: (1) the deductive effect-focused farmer, (2) the deductive cause-focused farmer, and (3) the imaginative effect-focused farmer.

In the following, we discuss important aspects of the most relevant findings and their consequences for understanding farmers' behavior. Subsequently we present strengths and limitations of comparing present and future statements and propose ideas for further research and policy implications.

5.1.1. Differences on aggregate level

On an *aggregate* level of analysis, the greatest differences in dependencies of future on present MMs were found for statements about the health and the natural capital. *Health* capital, with only 32% of the statements falling into the case 1 category, showed the lowest dependency of future on present statements of all capitals.

That is, for the health capital, only few of the future predictions were inferred from present explanations, suggesting a non-analytic and highly intuitive and experimental character for health-related mental representations. These results are consistent with those of previous studies. Severtson et al. [28] investigated the relationship between health consequences and emotions and suggested that beliefs about health consequences may be linked more to intuitive than analytical processing. Considering that health information is processed experientially, Epstein [29] notes that experimental processing is linked with affect, while analytical processing is described as affect-free. Bruch et al. [30] found that growers' agrochemical experience appeared to dominate their problem recognition process concerning health-related pesticide problems.

In the study area several interventions were carried out to improve the appropriate use of pesticides. These interventions were highly analytical, explaining pesticide use in a theoretical context and in the form of oral presentations instead of practical experiments. The analytical nature of the information campaigns so far conducted could explain the farmers' neglect of the recommendations concerning the use of protective equipment in the study region [23,30]. Therefore trainings

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on health protective issues should also consider affect. Practical experiences such as discussing health problems with pesticides experienced by farmers will lead to a higher uptake of information.

Natural capital, with 70% of the statements falling into the case 1 category, showed the strongest dependency of future on present statements of all capitals. That is, for natural capital, most of the future predictions were inferred from present explanations. Moreover most of the causal relations referred to relations governed by laws of physics. These findings suggest that farmers were intuitively using physical laws to describe causal relations of natural capital. These findings concerning natural capital are in line with the studies of Goldvarg, who noted that in MMs theory causation depends on physical possibilities [17].

The summarized findings demonstrate the importance of considering all livelihood capitals simultaneously to understand the differing dependency of a farmer's future on present MMs suggesting additional mechanisms as to how foresight is constructed among different capitals. Thereby it adds new insights to Aligica's theory [14] of the different epistemology of Future Studies. The findings give rise to the assumption that for certain capitals, for which causal inference was shown to play a smaller role, the tacit personal and social dimension of background knowledge may then play a greater role. For the case of pesticide risks, the social dimension of knowledge seems to play the greatest role in health capital.

5.1.2. Differences on individual level

On the *individual* level of analysis, i.e. summarizing all statements by each farmer, the farmers were classified into three types of statement patterns (type 1, the deductive effect-focused farmer; type 2, the deductive cause-focused farmer; type 3, the imaginative effect-focused farmer).

The deductive effect-focused farmer type showed a strong dependence of future on present statements combined with an asymmetry in cause, which means that for some causal relations farmers of this type focus more on effects to predict the future. It is important to note that the majority of the farmers were representatives of this group. These findings give rise to the assumption that for these farmers exogenous variables[4] play a dominant role in future predictions. The findings are consistent with Chermack's claim regarding the dominant role of exogenous variables in scenario planning [5].

The deductive cause-focused farmer type showed a strong dependence of future on present statements combined with an asymmetry in effect. In other words, this type of farmer focuses on known causes to hypothesize different effects in the future. In line with Johnson-Laird's and Byrne's theory of deductive thinking [31] these findings show that this type of farmer tries to cope with uncertainty in the future by presuming additional effects.

In summary the findings of *the deductive farmer types* showed that, at least for most of the farmers in our study area, the explanation of the present and prediction of the future differed in one-third of the cases. The results are consistent with studies of Harries [32] and Chermack [5] claiming that scenario planning is a process intending to provide a more complete view of the world than present MMs can do alone. Thus scenario planning can, by incorporating a long time frame, alter the MMs of farmers such that they consider more factors in more plausible situations. In other words, by incorporating more factors in their future MMs than in their present MMs, farmers from *the deductive types* were shown to follow this core aim of scenario planning.

The imaginative effect-focused farmer type showed the lowest dependence of future on present statements. The level of education of farmers of this type was low. The oldest farmer with the greatest experience in agriculture was in this category. It may be argued that this type of farmer has an even higher ability and openness to new causal relations than the deductive types, but farmers of this type will also have more difficulty relating their present behavior to the achievement of a desired future than deductive farmers. Bruch et al. [30] found that growers' agrochemical experience dominates their problem recognition process. Hence, consistent with Bruch's study [30], age and experience can be used as factors in explaining why *imaginative effect-focused farmers* can be found.

5.2. Strengths and Limitations

The comparison of present and future MMs revealed differences in dependencies of future on present MMs. However the method is a first attempt to enter into this difficult field of the epistemology of future studies it has shown some strength's but no doubt also harbors potential for improvement.

5.2.1. Strengths

First, the method constitutes a way of showing that explanation and prediction might differ and how they do so. For the case of pesticide application the results demonstrated that it is not sufficient to solely consider present MMs which is consistent with findings of Morgan [26] and Aligica [14].

Second, the method provides a measure for problem recognition, by providing a measure for the perceived difference of farmers' future and present MMs. This fills a gap highlighted by Engel et al. [33] defining problem recognition as accruing when a consumer recognizes a difference of a significant magnitude between what is perceived as the desired state of affairs and what is perceived as the actual state of affairs.

[4] Exogenous variables, referring to the definition of causal modeling, are variables with no causal links leading to them from other variables in the model (e.g. international financial markets, pesticide prices).

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Third, comparison of present and future MMs provides the means to further understand scenario planning. It provides the means to analyze beforehand whether farmers are more effect- or more cause-focused in their future MMs. Consistent with findings of Harries [32] and Chermack [34] our findings clarified how theories-in-use can be altered by revealing whether causes or effects should be stressed in information campaigns.

Fourth, the findings presented here suggest that inconsistencies of present and future MMs indicate mechanisms within processes of individuals' understanding and underline the role of future MMs in those processes. This is in line with the findings of Warren [35] and Harries [32]. Warren found that developing MMs from scenarios showed inherent inconsistencies and problems with scenarios illustrating conventional wisdom [35]. Harries argues that mechanisms, such as finding inconsistencies while building MMs, reveal the role of strategic planning as an organizational learning tool [32].

5.2.2. Limitations

First, the broad type of answers elicited through the open-ended questions generate a variety of MMs. This great variety of MM structures makes it extremely difficult to make inferences on the decisive prerequisites of each of the statements. We therefore propose adding some closed questions to the interview in order to additionally test the logic assumptions of the subject interviewed.

Second, in our particular case study one critical issue of the data used for the comparative study is the time which passed between the two interview sessions. Some circumstances of the study area changed during that time and might have influenced the second interview session, e.g. the increase in interventions to create farmers' cooperatives in the region by the governmental agencies. Also the perception of the present at the time of the future interviews had possibly changed in the meantime, e.g. some of the differences in the answers could be related to changes in perception. Therefore we recommend that the SMMA and the Future-SMMA interviews should be carried out as consecutively as possible.

Finally, the small sample number constitutes, even for this type of pure qualitative research, a limitation of this study. Even though the SMMA and Future-SMMA findings were demonstrated to be stable after 4–5 interviews, the comparison of the two showed a variety of possible thinking patterns. It would therefore be important to interview more farmers in order to weight the occurrence of different statement patterns.

5.3. Further research

From the dependencies found, interesting hypotheses concerning reasoning could be drawn, such as the hypothesis that differences in present and future MMs may lead to decision making failures. This hypothesis remains to be proven in an observatory experiment, monitoring what farmers with differences in MMs do, and comparing it to what they say they intend to do.

Moreover it would be interesting to compare the results reported here with results from farmers who have had special training in pesticide use, e.g. farmers who have learned how to use integrated pest managements techniques. This comparison may show whether training has an influence on farmers' MMs and on farmers' usage of their MMs to infer future predictions from present causal relations.

5.4. Policy recommendations

The differences found lead to new insights for policy recommendations, which may be adjusted depending on whether farmers focus more on causes or effects of the present to predict the future they desire. For example if the use of protective equipment (cause) leads to a decrease in health problems (effect) and farmers focus more on health problems (effect) then this effect should be stressed and the use of protective equipment be mentioned as one of different ways of decreasing health problems. If farmers focus more on protective equipment (cause) then this cause should be stressed and the decrease in health problems be mentioned as one of the various effects the use of protective equipment may have.

Furthermore the method presented here may serve as a starting point to learn more about farmers' backward planning processes. If a farmer formulated the desire to aim for a specific future (e.g. to change from traditional agriculture to organic) the reasoning leading to a certain behavior, implying a certain consequence for that future, should be investigated (e.g. if the person considers that he should manage to first lose a part of the harvest when switching to organic agriculture). This claim is in line with findings of Chermack et al. [36] and Marchais-Roubelat and Marchais-Roubelat [37] and implies that inconsistencies of present and future MMs may hinder backward planning from being successful. Therefore policy recommendations to improve backward planning may be derived from found inconsistencies in people's present and future MMs. Similarly Wiek et al. [38] and Scholz and Tietje [39] proposed, that policy recommendations should consider farmers' aspirations to actually reach a desired future.

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